Popular Astronomy.

Vol. XIII No. 5. May, 1905. Whole No. 125

SAYINGS OF GAUSS AND BESSEL.

(Translated by Betty Trier, Columbia University Observatory.)

FOR POPULAR ASTRONOMY.

The following translations from the published correspondence* of Gauss and Bessel are still of general interest, as being the opinions of these great men on questions important to-day as they were half a century ago.

Bessel constantly felt and expressed the need for skill in observations, and for the development of practical astronomy in general.

"I consider too many instruments in an observatory quite as harmful as too few,"† says Bessel, and explains later "I would scarcely have believed it possible to obtain such useful observations with my instruments; but it is incredible how much can be done with even second-rate instruments, if the observer only understands them exactly. But this, I believe, can never happen if he possesses or uses a superfluity of instruments; if he is confined to those absolutely essential, he will study them with redoubled energy, learn to know their every peculiarity and be satisfied only when he can by his computation overcome every error."‡

"To you (Gauss) we owe the recent increase of astronomical precision, on account of your method of least squares, and also because you have awakened an appreciation of accuracy which had vanished from the Earth since Bradley's time, and has only returned in the last eighteen years."¶

"You are quite right," he says again, "in considering the life of a practical astronomer somewhat exacting; I have long been aware of this, but have put myself above it, as I consider observations to be most important, and as practical astronomy is far behind theory. When we shall attain a perfected art of observing, and shall no longer confound with such an art the mere

* "Briefwechsel zwischen Gauss und Bessel," Leipzig, 1880.

† Bessel, Page 144.

‡ Bessel, Page 242.

¶ Bessel, Page 272.

ability to read seconds of arc accurately on a graduated circle, we shall be far less in need than we are now of mere observational contributions from certain persons, (meaning Gauss)".*

"How sad is the divorce of the purely theoretical from the practical mind."†

"Your plan for concerted lunar observations is highly desirable from all points of view; in the first place it will determine differences of longitude; in the second place, it will show with what precision lunar positions can be observed; in the third place, it will bring about a union between practical and theoretical astronomers. Such a union would do much to avoid a great deal that is useless and very displeasing to me, for I would like to see efficient coöperation. A few more such plans, and we shall soon see a close union where now there is only an utterly foolish egotism; the time will come, when all will rejoice in the work of each."‡

"The theory which I have advanced and fortified by a hundred practical tests, is being constantly strengthened; a fundamental determination may be accepted only when it is derived from observations lasting at least a year; night and day and summer and winter often present points of view which we have not anticipated and may not even recognize."¶

"I have from bitter experience acquired disrespect for the art of observing since Bradley's time: for Bradley, I believe, understood more by the art of observing than the mere division of seconds of time into tenths, as some now consider it."‖

"It is highly desirable, too," says Gauss, "that all astronomers should make use of the same mathematical elements for their computations."§

Gauss thinks all astronomers should possess a considerable knowlege of mathematics, and writers on astronomical matters should assume this knowledge on the part of their readers.

"Far-reaching analyses of trivial matters,—a lack of instinct for elegance, a constant endeavor to keep the student of astronomy always in the infant class of mathematics, all this clips the wings of enthusiasm."**

"According to my ideas, the right ascension of a circumpolar star is the thing that can be most accurately observed in the sky,

* Bessel, Page 358.
† Bessel, Page 199.
‡ Bessel, Page 313.
¶ Bessel, Page 347.
‖ Bessel, Page 311.
§ Gauss, Page 337.
** Gauss, Page 202.

and is therefore best adapted for the study of aberration, nutation, proper motion, precession, and possibly even annual parallax."*

In a letter of Bessel's written in December 1823, we find "personal equation" discussed for the first time.

"In the eighth part of my observations you will find some remarks concerning a very puzzling difference in the absolute time as observed by different people, which Maskelyne has already noted in 1794, and of which I have encountered examples myself.—There is a difference of a full second of time between Struve and me, and it has grown to this size from zero in 1814; between Maskelyne and Kinnebrook it was at the last 0″.8, and yet the latter must have made the utmost efforts to bring his observations into accord with Maskelyne's, because his dismissal was a consequence of this difference, which was considered purely a fault of Kinnebrook."†

Bessel's personal opinion of Jacobi is of interest: "We are doubly attached to Jacobi here, not only on account of his talent, but on account of his character as well, which does not in the least correspond with his inclination toward sarcasm, and which makes him very lovable after you have learned to know him."‡

Neither Bessel nor Gauss had very brilliant students in 1808, for Gauss wrote in that year as follows: "I hope indeed that you will now find it possible (in Düsseldorf) to live for scientific work only; for even practical work must give you far greater satisfaction than teaching the astronomical alphabet as far as B to a few average minds which must otherwise have remained permanently at A."¶

But matters had not improved in 1810. "I am conducting two courses this year," writes Gauss, "for three students; one of them is only fairly well prepared, one of them scarcely fairly, and the third is lacking in preparation as well as ability. Such are the hardships of a mathematical profession."‖

To this Bessel responds: "It is but seldom that I am lucky enough to have capable and energetic pupils, but it would be unjust of me to complain too loudly."§ Of his best pupil of that year, Thune, he says, "He would have made more progress, had

* Gauss, Page 171.
† Bessel, Pages 425 and 426.
‡ Bessel, Page 538.
¶ Gauss, Page 97.
‖ Gauss, Page 107.
§ Bessel, Page 166.

he not been led astray before this by tiresome philosophy courses so that he neglected his mathematics."*

Gauss seems to have held a very high opinion of Euclid; Bessel wrote to him: "You once said of Euclid that he must have known principles and theories of higher arithmetic, of which no direct traces can be found in his *Elements*; I hold a somewhat similar opinion about Bradley, and on the same grounds, because of the results he obtained."†

"I have again, "says Gauss," devoted some thought in my idle hours to a subject which I have had more or less in mind for forty years; I refer to the first principles of geometry; I do not know whether I have ever told you my views on this subject. I have considered a good deal of material here, and my conviction that we cannot found our geometry entirely on *a priori* considerations has been strengthened. It will probably be some time before I have a chance to elaborate my investigations with a view to making them public, and perhaps I will not have them published during my lifetime, as I dread the clamor of the Bootians if I should fully express my views.—But it is strange that beside the well known hiatus in Euclid's Geometry, to fill which all efforts so far have proved unavailing, and which will never be filled, there should be another lack in his geometry, which, to the best of my knowledge has never before been noted, and which it will be very difficult, although possible, to help out. This is a definition of the plane as a surface such that the straight line joining any two points of it shall lie wholly on the surface. This definition contains more than is necessary for the determination of the plane, and tacitly involves a theorem which should first be proved."‡

When Bessel found that a Doctor's degree would be very useful to him in Düsseldorf, he refused to apply for it to the authorities there, "For," said he, "I consider it wrong to request anything of people which they ought through mere courtesy to have offered unasked."¶

"All the apparent chance-happenings and coincidences which have at the last so weighty an influence in determining the course of a man's life, incline him to a recognition of the deeds of a higher Being. The puzzle of life we may never hope to solve here."‖

Gauss almost apologizes for taking so much trouble in locating

* Bessel, Page 166.
† Bessel, Page 311.
‡ Gauss, Page 490.
¶ Bessel, Page 123.
‖ Gauss, Page 453.

the church steeples to be used as geodetic stations; he says, "After all, it can matter but little to the Almighty whether we determine the geodetic position of a church steeple within a foot, or locate a star within a second of arc."*

Both Gauss and Bessel have expressed the enthusiasm and the respect they had for their work: "I will admit that I have often thought of a complete change of my position. But it is certain that if I am to remain permanently where I now am, the greater part of my earlier theoretical works, all more or less lacking completion, and which are of such a nature that I cannot force their completion at will, must go to the grave with me. For I neither can nor will publish anything incomplete."†

"I consider this undertaking (Bessel's Zones) as an absolute sacrifice for the good of science; I open the way to discovery for others, but I myself discover nothing. But you and I have long been accustomed to leave precious self in the background when it is a question of the advancement of science: Whoever begins to dread sacrifice of self is already half dead for science: in this respect however, I will be half dead only when I am wholly dead."‡

NEW YORK CITY.

USE OF DRAWINGS IN ORTHOGRAPHIC PROJECTION AND OF GLOBES IN TEACHING ASTRONOMY.

SARAH F. WHITING.

FOR POPULAR ASTRONOMY.

The use of the Celestial Globe can give the student the most just conception of the diurnal movements of the heavenly bodies. There are numerous globe manuals, so that it is my purpose merely to state the exercises selected as most valuable in our course, and the preliminary work in drawing which has proved a useful accompaniment.

The ideal equipment for these exercises requires such a number of full-mounted globes of moderate size and expense, that there is one for each two students. It is important that globes be selected in which the lithographed plates are clear, and the background of such color that the stars show well. There are few such globes in the market.¶

* Gauss, Page 412.
† Gauss, Page 410.
‡ Bessel, Page 421.
¶ The Gair Company, Brooklyn, N. Y., send out a twelve-inch globe which meets the conditions best of any I have found, since the Joslyn ten-inch globe is no longer made.

The following directions are given for the drawings which precede the globe exercises.

STUDIES OF THE VARYING LENGTH OF LIGHT, TWILIGHT AND NIGHT IN DIFFERENT LATITUDES, AND AT DIFFERENT SEASONS.

Materials:—unruled paper, compasses, protractor, and the celestial globe.

Note. The drawings to be made are projections upon that great circle which is the meridian of the place. The observer is supposed to be looking at the celestial sphere from outside, and from a point in the plane of the horizon due east. All small circles will be represented as straight lines.

Procedure. On seven sheets of paper make circles not less than fifteen centimeters in diameter. Through the center of each draw two diameters at right angles. Mark the horizontal one, which represents the horizon projected in a straight line HO, and the vertical one, which is the prime vertical ZN. Measure on the meridian with the protractor an angle eighteen degrees below the horizon on each side, and draw the small circle which is called the twilight circle. Finish the drawings to represent the conditions in different latitudes, by measuring an angle above the horizon at the right equal to the latitude, and drawing PP the six o'clock hour circle, and an angle at the left equal to the complement of the latitude, and drawing EQ, the equator, both projected in a straight line. Then measure on the meridian at each end, both above and below EQ, the angle of the Sun's declination at the solstices, viz. 23°.5, and draw the diurnal path of the Sun at these times. Write on the diurnal circles the dates of the equinoxes and solstices.

Complete the drawings for the following latitudes:—

1. Latitude 0°,—the equator. This will approximately represent conditions at Quito, Singapore, Lake Victoria Nyanza.

2. Latitude 23°.5,—the northern tropic, near which are situated Havana, Sandwich Islands, Hongkong, Calcutta, Assouan.

3. The latitude of the student's own station.

4. Latitude 48°.5,—nearly the latitude of Quebec, Vancouver, Paris.

5. Latitude 66°.5,—the polar circle, near which are Archangle, Iceland, Behring Strait.

6. Latitude 72°,—the North Cape within the polar circle.

7. Latitude 90°,—the Pole.

Inspect these drawings one by one and write upon each sheet conclusions. This inspection will readily show that in latitude 0°, Fig. 1, the twenty-four hours are divided between darkness, twilight and light; that the twilight at the equinoxes lasts one

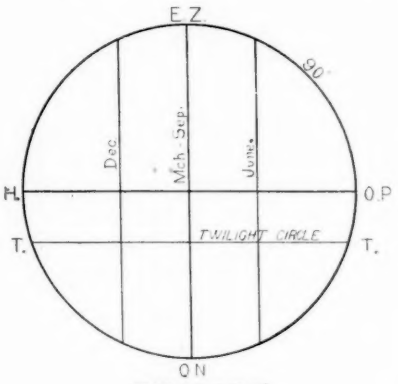


FIG. I. LAT. 0.

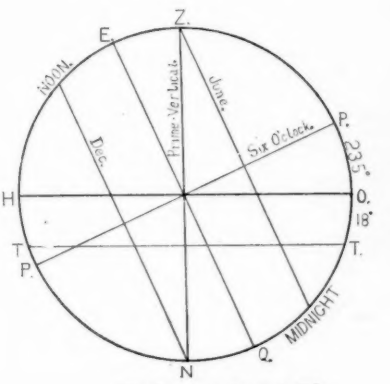


FIG. II. LAT. 23.5°.

hour and twelve minutes, since here the Sun's path is perpendicular to the twilight circle; that the noon altitude of the Sun at

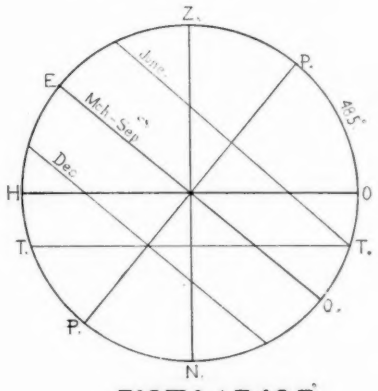


FIG. III. LAT. 48.5°.

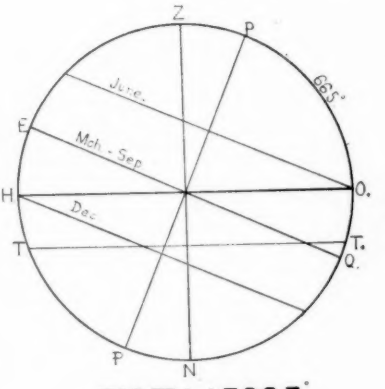


FIG. IV. LAT. 66.5°.

the equinoxes is 90°, at the summer solstice 66°.5 above the north point, at the winter solstice 66°.5 above the south point.

On the tropic, Fig. 2, it will be seen that the noon altitude of the Sun, June 24, is 90°, and by comparison with other draw-

ings, that the Sun can never appear on the meridian north of the zenith between the tropic and the polar circle.

The drawing for latitude 48°.5, Fig. 3, shows that this is the least latitude where the twenty-four hours can be divided into twilight and light, since the latitude plus the depression of the twilight circle is the complement of the Sun's declination in June, (48°.5 + 18° + 23°.5 = 90°), and therefore its diurnal path just grazes the twilight circle.

Fig. 4 shows that on the arctic circle the twenty-four hours at the summer solstice are all light, since the latitude 66°.5 is the complement of the Sun's declination in June (66°.5 + 23°.5 = 90°). The Sun's noon altitude in June is 47°, its midnight altitude 0°.

Fig. 5 shows that the noon altitude of the Sun within the arctic circle is equal to the elevation of the equator plus the

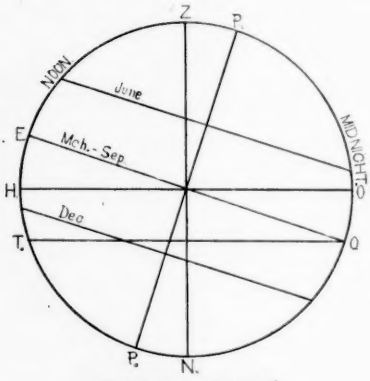


FIG. V. LAT. 72°.

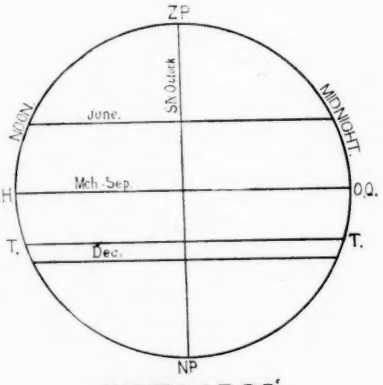


FIG. VI. LAT. 90°.

Sun's declination; the midnight altitude is equal to the Sun's declination minus the elevation of the equator.

Fig. 6 shows that at the pole the Sun's path in June is approximately parallel to the horizon and 23°.5 above it.

Finally, passing all the drawings in review, the conditions can be summarized in all latitudes from the equator to the pole in reference to darkness, light, and twilight.

Conditions at the winter solstice from the equator to the north pole:—

The hours of darkness increase from the equator to latitude 48°.5; where they are twelve hours. Beyond that darkness continues to increase to the pole where the darkness is continuous. The hours of twilight increase at the expense of day-

light from 0° to 66°.5 latitude, where the daylight becomes zero. Beyond this twilights decrease to zero at the pole. The hours of daylight decrease from the equator to latitude 66°.5 where they are zero.

Conditions at the summer solstice:—

Hours of darkness decrease from 0° to latitude 48°.5 where they are zero. Twilight increases at the expense of darkness from 0° to 48°.5 latitude, where it lasts all night, beyond that it decreases to latitude 66°.5 where it fills the twenty-four hours. Light increases from the equator to latitude 66°.5 where it fills the twenty-four hours, and beyond this continues for months.

Next, the conditions of each drawing should be studied from the globe, and the time of sunrise and sunset, and the length of day and darkness recorded. Problems can also be solved as to the conditions at various places often visited by travellers.

Other Exercises with Globes.

Instead of giving miscellaneous exercises in reading from the globes the coördinates of stars, it is well to give out a list of the twenty brightest stars* to be copied in the notebook, while four columns are prepared for records, two for coördinates read from the globe with flexible quadrant, and two for the same to be taken from some star catalogue for the epoch A. D. 1900†, or, from the ephemeris. After these columns are filled out and inspected, it will be seen that the right ascensions from the catalogue are not only more accurate but are greater than those read from the globe. The student's attention is called to the fact that the epoch of the star catalogue is A. D. 1900, that that of the globe is about A. D. 1850‡, that this difference between readings from catalogue and globe can result from but one of two things, either the stars have all moved, or the zero point of measurements has moved backwards. The emphasis of individual discovery is thus put upon the precession of the equinoxes.

The measuring of sidereal time and its relation to solar time is impressed by the familiar exercise of reading sidereal time by Caph, ¶, and verifying the same by the globe.

The student is directed to rule a page in the notebook in four

* A classified list of brightest stars is given in Upton's Atlas.

† The Catalogue of 1520 bright stars reprinted from the Harvard Annals is invaluable. The Ephemeris list gives the northern stars.

‡ The charts for the globe were made from the B. A. Catalogue Epoch 1850.

¶ See Todd's New Astronomy.

columns and to record on ten fair evenings the date, standard time, and estimated sidereal time by observation of Caph. The student is also to set the globe for the day and hour and record in a fourth column the true hour angle of the vernal equinox at that time. When the observation is taken at the observatory the sidereal clock itself is read for comparison.

On observatory nights the globes as well as maps are in constant use to show the positions of the objects on the observing list, as well as of the constellations in general. It is well that on the two-foot globe colored disks of paper be lightly stuck with wax to represent the positions of the Sun, Moon and planets taken from the ephemeris at some epoch, as January 1st. Turning this globe will give familiarity with the movements of these objects with reference to the horizon; and make clear the meaning of morning and evening star, opposition, quadrature.

This may seem like giving prolonged attention to elementary phenomena, but it is surprising how inadequate are lectures alone, though illustrated with excellent tellurians like the McVicar globe and the Gardener Season Apparatus, to give many students clear ideas, without their own work with drawing tools, note book and globes.

For students in mathematical courses who work trigonometrically with the astronomical triangle such graphical work is less necessary.

WHITIN OBSERVATORY,
WELLESLEY, Mass.

PREDICTIONS FOR THE TOTAL ECLIPSE OF THE SUN, 30TH AUGUST, 1905.

DAVID TODD AND ROBERT H. BAKER.

FOR POPULAR ASTRONOMY.

In the merely general prediction of an eclipse, no cycle is more useful than the 3-Saros period of 54 years 1 month.* In longitude the eclipse returns to the same general regions of the globe, but in latitude the displacement will usually amount to several hundred miles.

Doubling this period, the eclipse of next August at its second previous occurrence happened in 1797, far north in Greenland and the Arctic regions. The next return was the very notable eclipse of 1851, July 28, which attracted to the field in Sweden and Germany no less an array of astronomers than Adams, Airy,

* *Total Eclipses of the Sun*, by M. L. Todd, p. 194 (Boston: Little, Brown & Co. 1900.)

Bond, Dawes, Lassell, Piazzi Smyth, and Otto Struve. It seems to have been the occasion of the first American Eclipse Expedition to the continent of Europe; and it is especially noteworthy because Busch took the first photograph—a daguerreotype—of the corona. An excellent one it was, too, although made with a visual lens—and a divided object glass at that, the Königsberg heliometer.

Following this eclipse down by the Saros, we find its return in 1869, August 7, a distinctively American eclipse, with Professors Langley, Winlock and Shaler, Mr. Alvan G. Clark, Dr. Gould and Professor Young in the field, the last discovering the characteristic line in the coronal spectrum, and Whipple taking fine pictures of the corona, the first in America.

The next return came in 1887, August 19, when the track through Germany, Russia, Siberia and Japan brought well-remembered disaster to a score of expeditions. But the present year it falls on regions which for accessibility and chances of excellent weather are especially favorable.

In a survey of the entire track of this eclipse, we have had occasion to calculate the times of occurrence of the phases and other data for a wide choice of stations within the belt of totality.

Beginning with a point on the coast of Labrador, the track across the Atlantic Ocean has not been neglected, because a portion of this belt intersects the lanes of the numerous Atlantic liners; and useful drawings of the corona are quite feasible at sea, as well as snap shots of the inner corona with the highly sensitive films now everywhere commercially available.

Following are the circumstances for Labrador and twelve points on the Atlantic. For all the land stations the times of the phases are local mean time; for all the ocean stations, they are given in Greenwich mean time. The Besselian elements given in the *American Ephemeris* were employed in the computation. The ocean points are all on the central line; and in order to see the eclipse to the best advantage it is not necessary that the ship should be absolutely on this line. The length of time the total eclipse will be visible is not appreciably reduced if the ship is not more than ten or twelve miles either north or south of this line. But if more than forty-five nautical miles on either side of the central line, the corona will not be seen longer than a few seconds. In this case, if the position of the ship is known with great accuracy, especially its latitude, any one who notes the exact length of totality will make an observation of astronomical

value, although the error of the watch or chronometer may be entirely unknown.

Similar data regarding the eclipse follow for fifteen stations in Spain. This is the fifth total eclipse visible in this country within a period of sixty-three years. Doubtless this region will draw the largest number of observing parties, although Algeria, Tunis, Tripoli and Egypt present very attractive conditions, in spite of the afternoon Sun at increasingly lower altitudes. We have added also one station in the Balearic Isles. And for completeness and ease of reference, the data as published by Dr. Downing in *Nautical Almanac Circular* No. 19 are included.*

TOTAL SOLAR ECLIPSE, 1905 AUGUST 29-30.

	Lat.	Longitude (from Greenwich.)	Eclipse Begins.	Totality Begins.	Totality Ends.	Eclipse Ends.
LABRADOR.			Local Mean Time.			
	° ′	° ′	h m s	h m s	h m s	h m s
Domino Harbor	53 29N.	55 46W.	19 8 18	20 11 6	20 13 44	21 21 6
ATLANTIC OCEAN.			Greenwich Mean Time.			
	53 17N.	49 52W.	22 53 52.2	23 58 36.5	0 1 23.4	1 10 38.5
	52 21	39 15	23 0 1.2	0 8 28.0	11 32.0	24 3.9
	51 44	34 50	3 19.9	13 24.8	13 36.2	30 19.4
	51 22	32 46	5 2.3	15 54.2	19 9.1	34 5.8
	51 2	30 50	6 46.9	18 21.2	21 38.8	36 24.1
	50 40N.	28 58W.	23 8 33.3	0 20 50.6	0 24 11.0	1 39 14.4
	50 16	27 11	10 20.9	23 18.9	26 42.5	42 18 0
	49 52	25 28	12 11.0	25 48.2	29 15.1	45 11.1
	49 28	23 50	14 2.5	28 15.8	31 44.2	47 59.6
	48 37	20 43	17 52.3	33 12.4	36 46.4	53 52.1
	47 45N.	17 49W.	23 21 46.6	0 38 11.9	0 41 48.1	1 58 53.8
	45 55	12 30	29 58.2	48 9.1	51 50.9	2 9 17.9
SPAIN.			Local Mean Time.			
Coruna	43 21N.	8 25W.	23 4 11.4	0 25 10.2	0 26 37.3	1 45 24.0
Ferrol	43 30	8 14	5 10.3	25 29.8	28 6.9	46 12.3
Lugo	43 2	7 33	9 14.5	30 14.3	32 0.9	50 32.2
Luarca†	43 29	6 34	14 39	34 22	38 7	55 11
Oviedo	43 20	5 49	19 4.2	38 51.6	42 32.9	59 27.0
Leon	42 38N.	5 34W.	23 22 49.4	0 40 45.9	0 44 13.6	2 1 54.7
Valladolid	41 39	4 41	26 34.7	48 46.9	49 21.7	8 5.1
Palencia	42 3	4 28	27 44.9	48 19.9	51 39.6	8 45.1
Burgos	42 20	3 43	30 34.1	50 44.1	54 27.6	11 5.4
Soria	41 44	2 31	39 22.5	59 39.7	1 3 23.0	19 42.5
Ateca†	41 17N.	1 51W.	23 43 38	1 4 4	1 7 49	2 24 1
Castellon	39 59	0 4	55 19.5	15 47.5	19 14.5	35 49.0
Torreblanca	40 15	0 14E.	57 14.2	17 48.4	21 30.9	37 8.4
Palma de Mallorca	39 37	2 43	0 11 44.1	32 17.8	35 25.8	50 27.3

* *Local Particulars of the Total Eclipse of the Sun*, August 29-30, 1905. By A. M. W. Downing, Superintendent, London, 1904.

† Near.

LABRADOR.	Duration of Totality.	Mag. of Eclipse	Angle of Position (direct image) First Contact. N. Pt.	First Contact. Vertex.	Last Contact. N. Pt.	Last Contact. Vertex.	At Middle of Eclipse. Sun's Azimuth.	Sun's Altitude.
	m s		°	°	°	°	° ′	° ′
Domino Harbor	2 38.1	1.019	286	322	107	136	292 3	26 36
ATLANTIC OCEAN.								
53 17N. 49 52W.	2 46.9	1.021	286.3	322.9	108.2	132.6	298 38	30 26
52 21 39 15	3 4.1	1.022	287.7	322.3	109.8	125.6	311 39	37 27
51 44 34 50	3 11.4	1.021	288.3	321.9	110.4	121.6	317 46	40 21
51 22 32 46	3 14.9	1.022	288.7	321.8	110.7	119.0	320 44	41 43
51 2 30 50	3 17.6	1.023	289.0	321.7	111.1	117.6	323 44	42 59
50 40N. 28 58W.	3 20.4	1.023	289 4	321.6	111.4	115.6	326 42	44 11
50 16 27 11	3 23.6	1.023	289.7	320.9	111.7	113.4	329 46	45 21
49 52 25 28	3 25.9	1.023	290.0	320.5	111.9	111.2	331 55	46 15
49 28 23 50	3 28.4	1.023	290.3	320.1	112.2	107.1	335 32	47 24
48 37 20 43	3 34.0	1.023	290.9	319.0	112.6	104.8	341 18	49 13
47 45N. 17 49W.	3 36.2	1.023	291.4	317.7	113.1	100.5	341 27	50 48
45 55 12 30	3 41.8	1.024	292.5	314.3	113.8	92.5	359 42	53 14
SPAIN.								
Coruna	1 27.1	1.002	295	312	113	84	10 59	55 21
Ferrol	2 37.1	1.007	294	312	114	84	11 21	55 11
Lugo	1 46.6	1.003	294.8	311.1	113.4	82.6	13 19	55 27
Luarca*	3 44.7	1.020	294	308	114	84	11 26	55 11
Oviedo	3 41.3	1.019	293.5	306.7	114.7	82.6	17 16	54 42
Leon	3 27.7	1.014	294.4	306.8	114.1	80.7	18 17	55 16
Valladolid	0 34.8	1.000	296	307	114	78	21 36	55 47
Palencia	3 19.7	1.013	294.8	305.9	114.1	78.7	22 11	55 16
Burgos	3 43.5	1.020	294	304	115.	79	22 42	54 54
Soria	3 48.3	1.021	294.3	301.7	114.9	77.5	26 39	54 46
Ateca*	3 45.0	1.020	295	300	115	76	28 43	54 48
Castellon	3 27.0	1.014	295.2	297.2	114.4	72.6	34 13	54 44
Torreblanca	3 42.5	1.020	295	296	115	73	34 52	54 17
Palma de Mallorca	3 8.0	1.010	294	290	116	71	37 42	54 6

TOTAL SOLAR ECLIPSE, 1905 AUGUST 29-30.

ALGERIA.	Lat.	Long.	Eclipse Begins.	Totality Begins.	Totality Ends.	Eclipse Ends.
	° ′	° ′	Local Mean Time.			
			h m s	h m s	h m s	h m s
Djidjelli	36 50N.	5 47E.	0 33 39.4	1 54 12.9	1 57 29.5	3 11 24.2
Collo	37 1	6 35	38 10.3	58 12.5	2 1 47.8	15 7.6
Constantine	36 22	6 37	39 13.7	59 40.5	2 52.6	16 26.6
Philippeville	36 53	6 55	40 4.5	2 0 10.4	3 30.0	16 49.7
Guelma	36 28	7 26	43 48.2	3 43.9	7 16.4	20 16.0
Bone	36 54N.	7 46E.	0 45 18.5	2 5 14.5	2 8 6.0	3 21 12.5
Soukahras	36 17	7 54	46 58.3	6 41.0	10 16.9	23 0.2
Tebessa	35 24	8 6	49 23.5	9 39.5	12 29.9	25 33.7
TUNIS.			Local Mean Time.			
El Kef	36 10N.	8 41E.	0 51 46.9	2 11 32.5	2 13 44.2	3 27 0.2
Kairouan	35 41	10 6	1 0 50.0	20 15.9	22 56.1	34 58.7
Ras Mahara*	34 40	10 35	5 7	24 9	27 39	39 8
Sfax	34 44	10 46	6 5.2	25 1.3	28 29.6	39 52.9
TRIPOLI.			Local Mean Time.			
Tripoli	32 54N.	13 11E.	1 23 8.7	2 40 55.4	2 44 4.5	3 54 48.4
Lebda	32 28	14 14	29 43.2	47 20.2	50 40.8	4 0 16.6
Misrata	32 21	15 6	35 12.8	52 25.4	55 43.8	4 51.7
Bu Saida	30 58	17 40	52 18.9	3 8 14.9	3 11 29.9	20 42.2
Kudija	30 41	18 18	56 25.1	12 0.6	15 13.3	22 34.0
Muktar	30 14N.	18 54E.	2 0 31.8	3 15 52.2	3 19 2.8	4 26 3.7
Bishir	30 17	19 21	1 1.0	18 7.4	21 13.3	27 51.4
EGYPT.			Local Mean Time.			
Assouan*	24 13N.	32 54E.	3 26 28	4 33 25	4 35 58	5 35 33

* Near.

	Duration of Totality.	Mag. of Eclipse.	Angle of Position. (direct image) First Contact. N. Pt.	Vertex.	Last Contact. N. Pt.	Vertex.	At Middle of Eclipse. Sun's Azimuth.	Sun's Altitude
ALGERIA.	m s		°	°	°	°	° ′	° ′
Djidjelli	3 16.6	1.013	296.3	282.4	114.4	64.7	50 36	52 0
Collo	3 35.3	1.021	295.6	280.0	115.0	65.2	51 38	51 12
Constantine	3 12.1	1.012	296.4	279.9	113.8	63.2	52 39	51 25
Philippeville	3 19.6	1.014	296.0	279.7	115.4	65.5	52 22	50 58
Guelma	3 32.5	1.020	296.0	277.8	115.0	64.2	53 51	50 39
Bone	2 51.2	1.010	296.4	277.9	115.4	65.0	53 46	50 12
Soukahras	3 35.9	1.021	295.8	276.2	114.9	63.7	54 52	50 17
Tebessa	2 50.4	1.009	297.6	276.3	114.0	61.5	56 28	50 19
TUNIS.								
El Kef	2 11.7	1.005	296.3	274.8	115.3	63.5	56 10	49 39
Kairouan	2 40.2	1.008	297.1	271.7	115.6	62.7	58 56	48 26
Ras Mahara*	3 29.6	1.020	296	267	115	60	61 10	48 9
Sfax	3 28.3	1.020	296.4	268.3	115.8	61.6	61 18	47 56
TRIPOLI.								
Tripoli	3 9.1	1.014	296.5	260.6	115.9	59.2	66 47	45 43
Lebda	3 20.6	1.021	296.8	258.6	114.2	56.6	68 26	44 37
Misrata	3 18.4	1.021	297.4	257.3	114.3	56.2	69 45	43 43
Bu Saida	3 15.0	1.022	297.5	251.2	114.0	53.9	73 57	40 59
Kudija	3 12.7	1.021	297.5	249.9	114.0	53.6	74 52	40 16
Muktar	3 10.6	1.021	297.3	248.3	113.7	52.7	75 53	39 37
Bishir	3 5.9	1.018	297.7	248.3	116.9	55.9	76 14	39 5
EGYPT.								
Assouan*	2 33.0	1.018	294	227	112	45	89 47	23 26

Accessibility, likely freedom from cloud, and the Sun's altitude as well as all other conditions considered, the best stations appear to be those in the extreme north of Africa. At some of these, high elevations above the sea may be chosen; and at these the figure and brightness of the corona may be greatly enhanced, on account of the feebler absorption of the bluish rays of the corona. Such stations are well worth the extra trouble occasioned by occupying them. There are stations at still greater elevations in Spain, but there seems to be little likelihood of a clear sky.

My experience in Tripoli in 1900, as well as the meteorological observations since made there by Mr. Venables at my request, lead us to expect clear skies in this locality; but the difficulties of occupation are advanced to a maximum by the Turkish government, which even exacts a heavy duty on all instruments brought into the vilayet.

The Lick observers seem to me very wisely to have chosen Assouan. And it is interesting to note that the next time this eclipse comes round, 10th of September, 1923, these favored astronomers will again have a totality at their very doors, the total phase falling visible very near, if not exactly at, Mount Hamilton itself.

OBSERVATORY HOUSE, AMHERST, Mass.

* Near.

AN INTRODUCTION TO THE DIFFERENTIAL CALCULUS, BY MEANS OF FINITE DIFFERENCES. I.

COPYRIGHT BY ROBERDEAU BUCHANAN, 1905.

FOR POPULAR ASTRONOMY.

Article 1. *The usual method of explaining the Calculus by the Doctrine of Limits.* The principal difficulty met with by the student of the Calculus is in getting an idea of the purpose and scope of the subject, and more especially in understanding the meaning of differential, differential coefficient, etc. It is evident that he can make no real progress in this study until his mind grasps these elementary ideas.

The usual explanation of a differential now generally adopted is that of Limits. Euler, Professor Peirce of Harvard University Professor Courteney and nearly all the writers on this subject, give the explanation substantially as follows: Assume the equation

$$u = x^2 \tag{1}$$

Let x take an increment h making it $x + h$ then u assumes a new value

$$u_1 = (x + h)^2 = x^2 + 2xh + h^2 \tag{2}$$

The change in x is

$$(x + h) - x = h \tag{3}$$

and the corresponding change in u, is

$$\begin{aligned} u_1 - u &= x^2 + 2xh + h^2 - x^2 \\ &= 2xh + h^2 \end{aligned} \tag{4}$$

Here h may be taken as small as we please and at the limit h^2 is infinitely small compared with h and can be neglected.

Then

$$\frac{u_1 - u}{h} = 2x \tag{5}$$

in which h is the differential of x and $u_1 - u$ the differential of u hence we have the differential coefficient

$$\frac{du}{dx} = 2x \tag{6}$$

In some works this explanation is varied by first dividing equation (4) by h which gives

$$\frac{u_1 - u}{h} = 2x + h \tag{7}$$

Then, h being infinitely small compared with $2x$ can be neglected. Others say that here h may undergo any change of value without affecting x, so letting h diminish until it is zero we have equation (5) as given above.*

* James Haddon Examples and Solutions in the Differential Calculus. Weale's Series.

In Davis and Peck's *Dictionary of Mathematics*, Article *Infinitesimal*, this principle is very broadly stated.

"When several quantities either finite or infinitesimal are connected together by the signs plus and minus, all except those of the lowest order may be neglected without affecting the value of the expression. Thus

$$\left.\begin{aligned} a + dx + dx^2 &= a \\ \text{or} \qquad dx + dx^2 + dx^3 &= dx \text{''} \end{aligned}\right\} \qquad (8)$$

2. Professor Bledsoe in his *Philosophy of Mathemics** attacks this method of explanation, because in Equation 7, h is supposed to be equal to zero on one side of the equation but retained as a small finite quantity on the other. And also in equations (8) asks, Can the first one be exactly equal to a? (p. 64) And also "No one can look the principle fairly and fully in the face, that an infinitely small quantity may be subtracted from a finite quantity, without making even an infinitely small difference in its value, and yet regard it otherwise than absurd" (ibid p. 63) Professor Bledsoe states that this method is sanctioned by such names as Roberval, Pascal, Leibnitz, the Marquis de L'Hopital and others, and yet it is apt to inspire the student, that the calculus is "merely a method of approximation." (pp. 65, 70).

DeMorgan, a great name in mathematics has evidently himself seen the objections to this method and gives a long explanation of a limit (which however he makes no further use of); then steps over the difficulty by giving a number of differentials "without demonstrating them, therefor, or even defining them."†

Newton, one of the discoverers of the calculus conceived a line to be made by the motion of a point, its path, in fact; hence the names he adopts—fluents and fluxions.

Professors Rice and Johnson of the United States Naval Academy have published a calculus founded on the idea of rates and velocities, etc. The works of these three latter writers are not open to the objections which have been made to the method by limits.

3. *Author's explanation by means of Finite Differences.* On account of their analogy, one to the other, Finite Differences seem to be the natural explanation to the Calculus, when their diversity is also pointed out. This method is more general than those mentioned in the foregoing pages. Moreover it easily explains and verifies the objection raised by Professor Bledsoe.

* Published by J. B. Lippincott & Co., Philadelphia 1874, p. 212.

† De Morgan Differential Calculus, London 1842; chapter *i.*

It will be sufficient for our purpose at present to assume as a general equation, the following:

$$u = a + (b + cx)^2 \qquad (9)$$

First, let $a = 0$ $b = 0$ and $c = 1$ which gives the equation (1) of Article 1.

$$u = x^2 \qquad (10)$$

Now assume successive values of x, the independent variable, positive and negative and find the resulting values of u. Place the values of x in column 1, Example 1, and the resulting values

EXAMPLE 1, EQUATION 10. $u = x^2$

Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.
x	u	Δ_1	Δ_2	Δ_3
−5	+25			
		−9		
4	16		+2	
		7		0
3	9		2	
		5		0
2	4		2	
		3		0
−1	+ 1		2	
		−1		0
0	0		2	
		+1		0
+1	+ 1		2	
		3		0
2	4		2	
		5		0
3	9		2	
		7		0
4	16		2	
		9		0
5	25		+2	
		+11		
+6	+36			

of u in column 2, which is headed u. The proper signs of the quantities should be carefully considered and written whenever a sign changes. Next, form the column of First Differences, Δ_1,* (column 3) by subtracting algebraically each number from the number below it, in column 2 and placing the difference below the line, that is, 0 opposite the space between the two numbers. It will be seen presently that this position for the difference is the correct place, and it is important that it should be so placed.† This column is headed Δ_1, the usual designation for a *first difference*. Next in like manner form the column of *Second Differences*

* The character Δ in the Calculus of Finite Differences is a symbol of operation as d is in the Differential Calculus, it is often however taken to represent the Differences themselves; in the following examples it has this latter meaning.

† In works on Finite Differences the line of Differences is usually placed on the line of the primitive; or else the values of the function are placed on a line with the differences in columns below. The method described in the text is the more general and seems to possess more advantages than any other.

Δ_2 (column 4) subtracting algebraically as before, each number in column 3 from the one below it, and placing the difference *on* the line, that is, opposite the space between the two. This is the proper position for the second difference. This column is headed Δ_2 and in the present example is a constant 2. There are no Third Differences Δ_3 in this example since if we try to subtract our results equal zero and moreover all the higher differences must be zero also. The second differences being a constant are independent of the value of the function u.

4. The reader will now have but little difficulty in understanding the meanings of differential, and differential coefficient:

The differences of the values of x column 1 which are all unity are *practically* dx the differential of x; and the numbers column 3, the First Differences, are *practically* the first differential coefficient of the values of u in column 2, depending upon the values of x, column 1. And the Second Differences column 4 are *practically* the second differential coefficient of u. These numbers show the analogy of differences and differentials. The word *practically* used above alludes to their diversity which will be considered presently.

To show these statements, resume equation (10)

$$\left.\begin{array}{l} u = x^2 \\ \text{Differentiate} \quad \dfrac{du}{dx} = 2x \end{array}\right\} \tag{11}$$

This equation will *practically*, that is very nearly, give the numbers in column 3, the First Differences. But first an important distinction between a difference and a differential must be stated. The value $+5$ is the first difference belonging to the value of $u = +4$ or $x = 2$ and properly is placed *below* the line. The differential coefficient of $x = +2$, and $u = +4$ would properly stand *on* the line with u, so that its value would be between 3 and 5. Now by equation (11) compute various values of $\dfrac{du}{dx}$ and compare them with the example. They are, in equations of the second degree, correctly speaking, the means of the two differences above and below the line, thus:

If $x = -4$		$\dfrac{du}{dx} = 2x = -8$	*on* the line
$x = -1$		$\dfrac{du}{dx} = 2x = -2$	*on* the line
$x = +2$		$\dfrac{du}{dx} = 2x = +4$	*on* the line
$x = +2.5$	*below* the line	$\dfrac{du}{dx} = 2x = +5$	*below* the line

It should be remarked that for so low an order as the square the differentials and differences agree with one another more closely than they do in the higher powers, which will be shown by an equation of the fifth power on a subsequent page.

Resume equation (4) of Article 1.

$$u_1 - u = 2xh + h^2$$

in which h is the increment of x and is always taken as unity in Finite Differences. It is also so taken in Example 1, column 1. Hence we have

$$u_1 - u = 2x + 1 \qquad (12)$$

from which we can compute the first differences, remembering that they fall below the line, and we have as follows:

$$\begin{array}{rl} \text{If } x = -4, & u_1 - u = 2x + 1 = -8 + 1 = -7 \\ x = -1, & u_1 - u = 2x + 1 = -2 + 1 = -1 \\ x = +2, & u_1 - u = 2x + 1 = +4 + 1 = +5 \\ x = +2.5, & u_1 - u = 2x + 1 = +5 + 1 = +6 \end{array}$$

The last value + 6 should fall half a line below the position of $x = 2.5$ which brings it upon the line below. We see here that universally for any given value of x the differences and differentials have not the same values.

Differentiate equation (11) a second time

$$\frac{d^2 u}{dx^2} = +2$$

a constant which is the value in Example 1, column 4 of the finite differences.

5. *Statement of the objections to the usual Method by Limits.* Equation (4) is a correct equation in Finite Differences provided h is a constant, usually taken as unity. With this value the equation gives

$$u_1 - u = 2x + 1$$

But as, Equa. (11) $\quad \dfrac{du}{dx} = 2x$

We have $\quad \dfrac{du}{dx} = (u_1 - u) - 1$

from which the differential coefficient of equation (10) may be computed from the finite differences, as we have shown above. We see also that to form the differential coefficient the quantity h^2 or unity disappears by numerical subtraction merging into the term $(u_1 - u)$. By the method of limits this quantity h is divided out in order to get rid of it as a factor to $2x$ giving the equation 7 as follows:

Equation 7, $\qquad \dfrac{u_1 - u}{h} = 2x + h$

in which h in the second member decreases until it disappears

while in the first member it is retained as an infinitely small quantity then called dx. This is by far the most unmathematical feature of this method. There is also another point. The equivalent of

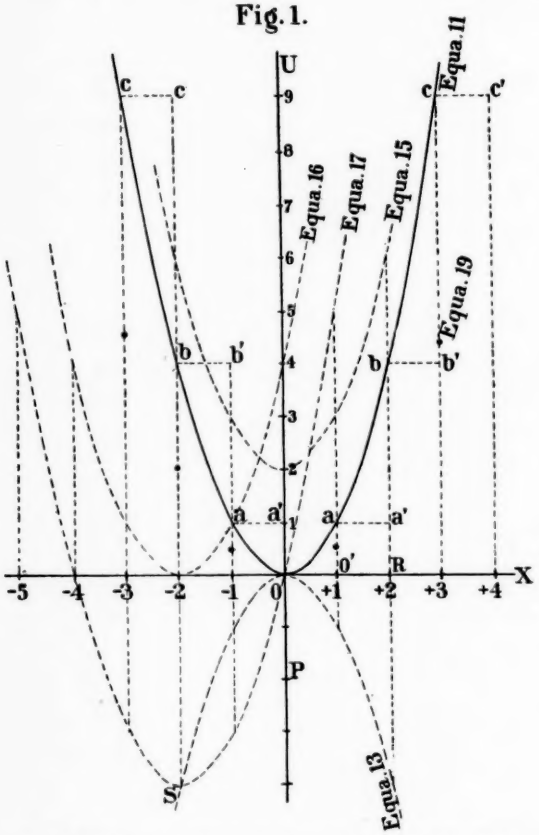
$$\frac{du}{dx} \quad \text{is not} \quad \frac{u_1 - u}{h}, \quad \text{but;} \quad u_1 - u$$

Another objection noticed, is that equation (7) above given, is a correct equation in Finite Differences if h is taken equal to unity, which gives

$$u_1 - u = 2x + 1$$

but it would hardly be suitable to let this term decrease until we

Fig. 1.



have $1 = 0$! so the notation h is substituted. This constant unity is the foundation of the theory of Finite Differences. With

the quantity h, the above equation becomes equivocal. When h is unity or finite the equation is one of Finite Differences; but when h is infinitely small or zero it is supposed to be a differential equation.

The doctrine of limits cannot in this manner be applied to an equation of Finite Differences in which the whole essence and life of the equation depends upon this quantity h being a *constant* and a *finite* quantity. In order to find the differential coefficient from the finite difference this method makes the constant h disappear by division; the author's method on the other hand makes it disappear by subtraction which leaves the *absolute zero*. This subject will be still further examined on a subsequent page.

(CONCLUDED IN JUNE-JULY NO.)

THE THOTH AND THE AMENTHES.

PERCIVAL LOWELL.

Connected with the conduct of the canals is a phenomenon, examples of which were early noted by Schiaparelli, and of which a striking instance came to light during the last opposition, in 1903; what may be called the hibernation of a canal for a longer or shorter term of years. What observation discloses is certainly curious. For several successive oppositions a canal will be seen in a definite locality, as permanent in recurrence as it is permanent in place, a well recognized feature of the disc. Then to one's surprise, with the next return of the planet, it will fail to appear, and will proceed to remain obliterate without assignable cause for many Martian years, until as unexpectedly it will be found what and where it was before. Neither to deposition of hoar-frost, such as frequently whitens whole regions of Mars, nor to other circumstance can be attributed its disappearance. Without rime or reason it has simply ceased to be and then as simply come back again.

Such bo-peep behavior is quite beyond and apart from the seasonal change in visibility to which all the canals are by their nature subject. For being creatures of the semi-annual unlocking of the water congealed about the polar caps, they quicken into growth and visibility, each in its season, and as regularly die out again. Different, however, is the phenomenon to which I now refer. In it not a seasonal but a secular change is concerned. The season proper to the canal's increase will recur in due course,

and the canals round about it will start to life, yet the canal remains unquickened. Nothing responds where in years past the response was immediate and invariable. The canal lies dormant spite of seasonal solicitation to stir.

Such curious hibernation was early hinted to the keenness of Schiaparelli, and most incomprehensible as well as difficult of verification at that stage the phenomenon was. That the phenomenon was a fact, however, he assured himself. But at the last opposition an event of the sort occurred which, from the length of time the planet was kept under observation, combined with continued suitableness of seeing, furnished a key to the problem's solution. In the light of what then happened, taken in connection with the side-lights thrown upon it by the canal's past and by the knowledge we have meanwhile gained of the planet's physical condition, the riddle of the phenomenon may in part at least be read, and most interesting and instructive the reading proves to be.

Among the initial canals detected by Schiaparelli, in 1877, was a tricrural set of lines recalling the heraldic design of three flexed legs joined equiangularly above the knees. It lay to the east of the Syrtis Major and he called its three members the Thoth, the Triton and the Nepenthes. Starting from the head of his gulf of Alcyonius, at a point now known to be occupied by the oasis called Aquae Calidae, the Thoth started south inclining westward as it went till in longitude 267° and latitude 15° N., it met the Triton, which had come from the Syrtis Minor with similar westward inclination. To the same point in the same manner came the Nepenthes. Part way along the course of the latter was to be seen a small dark spot, the Lacus Moeris, which he estimated at 4° in diameter. Some of the markings were easier than others, the easiest of all being the Lacus Tritonis, a largish dark spot at the common intersection of all three canals; but that none of the markings were remarkably difficult is sufficiently shown by their detection at this early stage of Schiaparelli's observations*. It is worth noting also that he discovered the southern ones first; the Thoth not being seen till March, 1878, the seasonal longitude of the planet, that is the longitude reckoned from its vernal equinox, at the time being $\odot 7°$. I shall make frequent use of the seasonal longitude, and print it in italics after the symbol for the Sun, as from it may be deduced the season of the planet's year. As his then recognition of these canals witnesses, they must have been among the most evident

* See Schiaparelli Memoria I §161.

on the disc. And the point is emphasized by the fact that he failed at this opposition to detect the Phison and the Euphrates as separate markings.

Much the same the three canals appeared to him at the next opposition of 1879, the Thoth being seen at its several presentations from October 5, ⊙*304*°, 1879, to January 11, ⊙*356*°, 1880. The only important change, indeed, was that the Syrtis Major had encroached upon the Nepenthes to the west, an event which does not here concern us. The Lacus Moeris was still there*; while the Triton continued on past the mouth of the Syrtis Minor on the west of Hesperia to the bay on the eastward side of the peninsula. This change also is not material to our present point. It will be observed that I keep the aquatic names, but I do so without implying their aquatic character.

At the next opposition a noteworthy alteration occurred, the full significance of which escaped recognition. Schiaparelli saw, at the place where the Thoth had been, two lines which he took for a gemination of that canal, one of which followed the course of the old Thoth, while the other went straight from the Sinus Alcyonius to the little Syrtis, or more precisely, to the junction of the Triton and the Lethes. It was not the Thoth, however, but something unsuspected of more importance†. The dates of the Thoth's appearance were November, *351*°, and December, ⊙*6*° (?) 1881, and again at its recurrent presentations on January 29, ⊙*27*°, February 6, ⊙*31*°, and March 10-11, ⊙*45*°, ⊙*46*°. On February 3, ⊙*30*°, 1882, it appeared geminated as above described.

In 1884 the Thoth showed really double, the western line being much the stronger, "una delle piu grosse linee que si vedessero sul disco."‡ That neither branch went further than the meeting place with the Nepenthes argues that it was indeed the Thoth that was seen. Schiaparelli himself had doubt on the subject, although he drew the double canal he saw due north and south from the tip of the Sinus Alcyonius to the junction, but nevertheless along the 263° meridian.

In 1866‖ and 1888¶ the system was in all essentials what it had been in 1877 and 1879, except that the Thoth and Nepenthes were double and were more minutely seen. In 1886 the Thoth was visible from February 2, ⊙*68*°, to May 23, ⊙*117*°, under

* See Schiaparelli Memoria II §§397-401.
† See Schiaparelli Memoria III §§541-542.
‡ See Schiaparelli Memoria IV §671.
‖ See Schiaparelli Memoria V §777.
¶ See Schiaparelli Memoria VI §914.

the aspect of a diffuse streak. In 1888 it appeared April 29, ⊙*126*°, May 8, ⊙*131*°, June 2-13, ⊙*146*°, July 21 (?), ⊙*169*°. In April it was confused; in June geminated, at first confused; and then for certain on the 12th and 13th.

Here then was a system of canals and spots which for six Martian years had been a persistent and substantially invariable feature of the Martian surface. Any changes in it had been of a secondary order of importance, while its general visibility was of the first. It is possible then to judge of my perplexity when in beginning my observations in 1894 no sign of the system could I detect. Of neither the Thoth, the Triton, the Nepenthes nor the Lacus Moeris was there trace. And yet from the other canals visible, it was evident that the disc was quite as well seen as it had been by Schiaparelli. Not only were practically all his canals there but many smaller ones were to be made out. And the same was true with the spots, a host of such not figured by him appearing here and there over the planet's surface. The nearest approach to its detection appears in a drawing by Mr. Douglass on September 20, in which it is very possibly represented.

Nor was this all. Instead of the Thoth, another canal showed straight down the disc from the Syrtis Minor to the Aquae Calidae. This canal was as unmistakable as the Thoth had been before to Schiaparelli. It was among the first to be detected and continued no less conspicuous to the end, the dates at which it was seen being July 10, ⊙*240*°, August 14, ⊙*262*° and October 21, ⊙*304*°. I called it the Amenthes, identifying it with the canal so named in Schiaparelli's chart published in "Himmel und Erde" of the *ensemble* of his observations from 1877-1888. But in his Memoirs he never called it so, seeing it, indeed, only in 1881-2 and deeming it then the Thoth. Nevertheless, in 1894 it was the conspicuous canal of the region and what is more had come, as it proved, to stay.

The invisibility of the Thoth continued for me the same during the succeeding oppositions of 1896-7 and 1901. (In 1898-9 I was unable to observe owing to ill health). At the former opposition I drew it in 1896 on July 28*, ⊙*279*°, August 26, ⊙*297*°, September 2, ⊙*301*°, October 5*-9, ⊙*321*°, seeing it single; and in 1897 on January 12-19*, ⊙*13*°, February 21, ⊙*30*° and March 1, ⊙*34*°. It was single but with suspicions of doubling in January and double in February. In the course of these oppositions some other observers depicted the Thoth and made out the Lacus

* Course northwestward instead of due north.

Moeris. I was never able to see it myself, though I searched for it on more than one occasion. As for the Thoth, I had come to consider it and the Amenthes one, attributing their diversity of depiction to errors in drawing. For while the Thoth remained to me obstinately invisible, the Amenthes presented itself as substitute so insistently as to make one of the most obvious canals upon the disc. Other canals appeared in the region from time to time not down in Schiaparelli's charts, such as the new Nepenthes, a line along the parallel eastward from the Libyan bay and the Libycum, also leaving the bay straight for the Aquae Calidae, but the Amenthes was throughout the dominant line. Lines it would be more precise to say, for the canal in 1901 was the greater part of the time double. Its appearances were in 1901, on April 3-6, ⊙*87*°, single and confused double; on May 9-11, ⊙*103*°, double, once single; on June 16-22, ⊙*121*°, double.

One exception only was there to this state of things. On June 16, 1901, my notes contain this adumbration of a something else: "Amenthes sometimes appeared with a turn to it two-thirds way up; two canals concave to the Syrtis Major."

So matters opened at the opposition of 1903. With the advent of the planet and the presentation in due course of Libya in February, the Amenthes duly appeared much as it had showed at the opposition before only less salient. It was a confused and narrower double. Suspected on the 16th of that month, it was definitely seen from the 18th to the 23rd. Of the Thoth no mention is made either in the notes or in the drawings. When the region came round again in March, the Amenthes was again there showing more feebly, however, than it had in February, considering the better seeing prevailing in March, although the planet was considerably nearer us. The canal was fading out; a fact further witnessed to by the following note made on March 25: "Throughout this opposition thus far the dark triangle tipped by Aquae Calidae has been sharply divided in intensity from the Amenthes, which is very narrow and exceedingly faint." Still was there no trace of the Thoth. The region was observed February 18-23, ⊙*87*°, March 19-28, ⊙*101*°.

With the April presentation entered a new order of things. When the region first became visible, on the 16th, the Amenthes could still be seen and alone; but on the 19th, as the relative falling back of the Martian longitudes swung the region nearer the center of the disc, the Thoth appeared alongside of it. On the 20th, ⊙*114*°, the Thoth showed alone. Unmistakable it was and just as Schiaparelli had drawn it, accompanied by the Triton and

the curved Nepenthes. The thing was a revelation. What before I had seen only in the spirit of other's drawings, stood there patent to me in the body of my own; while the Amenthes, to which I had so long been accustomed, had vanished into thin air. Only a trace of it was now and then to be made out. So startlingly strange was the metamorphosis that I could not at first trust my eyes and questioned the broken line, which had replaced the straight, for some ocular deception. But nothing I could do would rectify it. The Amenthes was gone and the Thoth stood in its stead. So it continued to the 30th. Of the Lacus Tritonis only so much was discernible as is foreshadowed in the following note made on April 25: "Crossing of the Thoth and Triton more visible than the canals themselves."

At the next presentation, May 26-June 8, ☉*133°*, the phenomena were repeated, and with increasing clarity. And then of a sudden on May 29, I saw the long-given-up Lacus Moeris. There it was indubitably. And its definiteness was the most astonishing part of the affair. It was no question of difficult detection. Indeed, I had not been on the lookout for it, having searched the region too often fruitlessly before to have left incentive to search again. And so when I was not searching, the thing of its own accord stepped forth to sight. It was a small round dot, like to any other oasis and showed as it were a black pearl pendent by the Nepenthes from the Syrtis' ear. For the Libyan bay made a dark projection of the sort high up on the Syrtis' eastern side from which the Nepenthes, precisely as Schiaparelli had drawn it, curved down to the point where the Thoth and the Triton met. All three canals were geminated, the gemination being about 3° wide.

And now occurred the last act in the drama. In July the Amenthes reappeared, showing alongside of the Thoth-Triton and thus removing any possible doubt as to their separate identity. It had, indeed, become the stronger of the two, the Amenthes having gained in strength in the interval between June and July and the Thoth-Triton having lost. The lines were in process of relapsing into the *status quo ante*. Had these three presentations not been watched, the brief apparition of the Thoth-Triton had been missed and with it the revealing of its curious character, and of certain deductions thereupon. Region observed June 30-July 10, ☉*150°*.

First among these is a truth of which I have long been convinced, to-wit: that when a seeming discordance arises between the portrayals of a canal, it is commonly not a case of mistake

nor of change, but one of separate identity. The canal has not shifted its place, nor has an error been committed; the fact is that one canal has been observed at one time, another at another.

So it was here, and thus were the old and the new observations reconciled. There had been no mistake in either. Two separate canals accounted for the discrepancy and only an unfounded distrust of the accuracy possible in such observations was to blame for any failure to recognize the fact.

Now scrutiny of the notes upon the appearances of the two canals, together with their labelling by the seasonal longitudes of the planet at the dates they were made, discloses a curious relation between the two. The seasonal longitudes are important as they date the phenomena according to the Martian calendar. Ordered thus, the successive aspects reveal first a seasonal change in each canal and then over and above this a secular one. And this secular change was such as to cause the two canals to alternate in visibility. When the one was present the other was not and vice versa.

Only two apparent exceptions occurred to this general rule. The first, which took place in 1881, was not recognized as such and the data are wanting to explain it. The second occurred in 1903, and here we have the details, and the light they throw upon the matter is significant.

From the great number of drawings made of the planet in the course of my observations of 1903, it has proved possible to construct the curves of visibility or cartouches, as I have called them, of a great many of the canals, of 85 of them in all. Among the 85 thus found, the Thoth, the Triton, the Nepenthes and the Amenthes are numbered.* Each cartouche portrays its canal's seasonal behavior and amongst other characteristics records the time at which the canal was at its minimum visibility or its dead-point of growth. When the cartouches are arranged according to the co-latitudes, or distances from the north polar cap, of their respective canals a steady progression in the date of the minima appears as one goes from the pole toward the equator. So exact is this progression that from the latitude it is possible to predict the date of the minimum for a given canal within relatively narrow limits. For the means of the canals for the different zones of latitude come out with an accuracy which vouches for the law. To the law a few canals apparently do not conform—all but one of which are susceptible of explanation—and precisely among these exceptions, making indeed the chief of

* See Mem. in the Proceedings of the Amer. Phil. Soc., 1903.

them, fall the Thoth, Triton, Nepenthes and Amenthes. The mid-latitudes of the Thoth and the Amenthes are 21° N., and 15° N., respectively. Now for canals of the mean mid-latitude, 18°, the minimum should have been about 42 days after the summer solstice of the northern hemisphere. Instead of this it was only 25 days after for the Thoth; while it was 68 for the Amenthes. Both canals were, therefore, *extra-ordinem*, the Thoth-Triton by reason of being too previous, the Amenthes of being too late.

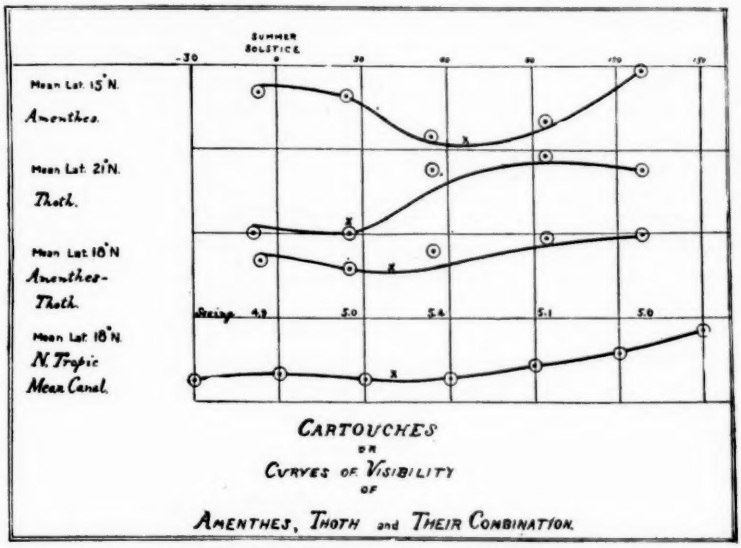
But if the mean of the two minima be taken, we find for the minimum of the system Thoth-Amenthes 46 days after the summer solstice or almost exactly the date of the minimum of the mean canal at their mid-latitudes.

A more accurate determination may be made directly. If instead of taking the mean of the means, we seek the results of considering the two canals as part of one manifestation by plotting the visibility curve of the Amenthes-Thoth considered as one marking, whose mean latitude is 18° N., we find a curve whose minimum falls at 40 days after the summer solstice, a result substantially the same as found by taking the average mean of the two, and differing from the minimum of the mean canal at the latitude (18° N.) as much on the one side as that does on the other.

Still further light is thrown on the subject by comparison of the cartouches of each canal and of their combination. Inspection shows that at first the Amenthes was seen alone and was in process of waning; that as it further waned the Thoth became visible; that the Amenthes continued to die out while the Thoth increased; and that finally the Thoth proceeded to fade away and the Amenthes to increase again. The cartouches that show this are presented opposite, stars pointing the minima.

Now the fact of secular change in the first place, and the further fact of alternation between the two canals in the second, lead to a conclusion of some moment. Knowing as we now do that mutable form of matter, the liquid, is largely absent from Mars, that there are no large bodies of water on the surface of the planet and very little of it in any form, we perceive no material means by which such local change in appearance from year to year could be effected. Indeed, even the presence of water would not render the explanation more feasible by the supposition of freshet or other inundation, since if such were able to cause a new marking it could not on that account obliterate the old. There could be no selective action by which the one should be taken and the other left. Nor could meteorological causes very

well produce what we see since they would be too impotent, it would seem, to decide that of two possible effects, alike except for a slight shift of locality, and only two, the one should always occur to the exclusion of the other. A year might be wet or dry but it could not well be wet in one place invariably when it was dry in another substantially the same and, what is the crux in the matter, never productive of any mean between the two except as the one gave of its humidity to the other. We are, therefore, led to the conclusion that the two canals do not wax and wane



EXPLANATION OF THE CARTOUCHES.

The percentage of visibility of the canal at each of its presentations is marked by the points within the circles; the ordinates denoting the percentages from zero, the lower line, to one hundred, the top one, while the abscissæ record the time in days before and after the summer solstice of the northern hemisphere. Correction for distance is included in the position of the encircled points; correction for the seeing is expressed by raising or depressing the curve.

separately from natural causes but are in truth alternatives so connected that the one should increase as the other decreases and vice versa. To explain this state of things the most probable supposition we can make is that they are so constructed, and that the one lies fallow while the other is at work. It is easily conceivable that a limited water supply should involve a necessity of the sort. It may well be that after one district has enjoyed the water and its results for a certain period, the supply should then be turned for a time into a neighboring one to be turned

back again after a while. The idea follows as a corollary from the theory that the canals perform the office of water supply, and in so far strengthens that theory itself.

Lowell Observatory, Bulletin No. 8.

RELATIVE MASSES OF BINARY STARS. I.

STEPHEN MARSHALL HADLEY.

I.

On the Motion of the Center of Gravity of a Binary Star With Respect to a Neighboring Star, and the Relative Masses of the Two Components of the Binary.

Let A and B denote the two components of the binary of which A is the brighter, and let C represent the neighboring star.

If we have a series of observations of A and B extending over an entire period of a binary or over the greater part of a period, giving the micrometrical measures of the position angles and distances of B with respect to A, also a series of observations of A and C, giving the micrometrical measurements of the position angles and distances of C with respect to A, the relative masses of A and B and the motion of their center of gravity with respect to C may be found from these observations.

In the case of a close binary if the position angles, θ^1 and distances ρ^1, of C with respect to $\frac{AB}{2}$ are given, the coördinates (θ, ρ) of C with respect to A may be found as follows:

Let G be the middle point of the line joining A and B.

(p, s) the position angle and distance of B with respect to A.

ϕ the angle ACG.

From the triangle ACG. the following equations are written:

$$\sin\rho\,\sin\phi = \sin\frac{s}{2}\,\sin(\theta' - p)$$

$$\sin\rho\,\cos\phi = \sin\rho'\cos\frac{s}{2} + \cos\rho'\sin\frac{s}{2}\cos(\theta' - p)$$

$$\cos\rho = \cos\rho'\cos\frac{s}{2} - \sin\rho'\sin\frac{s}{2}\cos(\theta' - p).$$

Noting that ρ' and s are very small quantities their cubes may be neglected, and putting

$$\frac{s}{2}\sin(\theta' - p) = \lambda\,,\quad \frac{s}{2}\cos(\theta' - p) = \mu$$

we have, by developing $\cos\rho$,

$$1 - \frac{\rho^2}{2} = \left(1 - \frac{\rho'^2}{2}\right)\left(1 - \frac{s^2}{8}\right) - \rho'\mu.$$

whence

$$\rho^2 = \rho'^2 + 2\rho'\mu \quad \text{(neglecting higher terms)} \qquad (1)$$

$$\tan \phi = \frac{\lambda}{\rho' + \mu}$$

$$\theta = \theta' \pm \phi . \qquad (2)$$

Whether ϕ is to be added or subtracted must be determined from the relative values of p and θ.

Development of Formulæ.

Let

ρ = the angular distance from A to C,
θ = position angle of C with respect to A,
x, y = the rectangular coördinates of A with C as origin,
x', y' = the rectangular coördinates of the center of gravity O, of A and B, with C as origin,
ξ, η = the coördinates of O with A as origin,
s = the radius vector of AB,
p = the position angle of B with respect to A,
k = the ratio of the distance of the center of gravity of A and B from A to the whole distance between A and B.

The coördinates of the center of gravity, O, of A and B are

$$x' = x + \xi$$
$$y' = y + \eta$$

With the origin at A these reduce to

$$x' = -ks \cos p + \rho \cos \theta$$
$$y' = -ks \sin p + \rho \sin \theta$$

On condition that the motion of the center of gravity, O, of the binary with respect to C is rectilinear its coördinates will be of the form

$$x' = \alpha + \beta\tau$$
$$y' = \mu + \nu\tau$$

in which α is the difference in declination at some assumed epoch between the center of gravity of A and B and the third star C, β is the relative annual proper motion in declination between C and the center of gravity of A and B, when τ is expressed in years.

τ is the interval of time between the date of observation and the assumed epoch.

μ, ν and τ, are corresponding data for motion at right angles to the hour circle.

By equating the above values of x' and y' the following equations are obtained:

$$\left.\begin{aligned} \alpha + \beta\tau + ks \cos p &= \rho \cos \theta \\ \mu + \nu\tau + ks \sin p &= \rho \sin \theta \end{aligned}\right\} \qquad (3)$$

In these equations τ, s, p, ρ *and* θ will be known from the record of the observations. Each pair of observations will furnish two equations of the form of equations (3).

The data of the problem will be the observed position angles, θ, and distances, ρ, of the optical companion C, referred to the bright component A, and similar measurements, p and s, of the component B of the binary, for the dates of the available observations of C.

For the application of these formulæ to the cases of the binary systems whose relative masses are hereinafter investigated I have made use of all the observed data contained in the library of Washburn Observatory and in the presentation of these data the following abbreviations will be used in the tables.

Σ = William Struve
0Σ = Otto Struve
$H\Sigma$ = Herman Struve
Δ = Dembowski
W = Winlock
Du = Dunér
β = Burnham
Pe = Perotin
Gl = Glasenapp
S = Comas-Sola
C = Comstock
Sp = Schiaparelli
L = Lewis
Pr = Pritchett
Ba = Barnard
A = Aitkin
Hl = Hall

a = Annals H. C. O.
m = Astronomische Nachrichten,
q = Astronomical Journal,
c = Catalogue des Étoiles Doubles et Multiplies, Flammarion,
f = Double Stars, Burnham,
g = Étoiles Doubles, Dunér,
s = Measures Micrometriques d' Êtoiles Doubles Le Professeur S. de' Glasenapp,
i = Misure di Stelle Doppie II, Dembowski,
j = Monthly Notices R. A. S.
*b*1 = Observations de Pulkova, Vol. IX,
*b*2 = Observations de Pulkova, Vol. X,
h = Observations of Double Stars of Asaph Hall,
d = Publications de L'Observatoire Central Nicolas, Series II, Vol. XII.
l = Publications of the Yerkes Observatory Vol. I.
n = Publicaziona Del Reale Osservatorio Di Brera in Milano No. XXXIII.
o = Unpublished Observations by Professor Comstock.

II.

Determination of the Relative Masses in the System σ Coronæ.

$\alpha = 16^h\ 11^m \qquad \delta = +34^\circ\ 7'$

This star was discovered by Sir William Herschel August 17th, 1780. The star has been well observed over a sufficient arc of its orbit so that the elements of the orbit are well determined. According to See* the period is 370.0 years. The component is approaching apastron which it will reach in the early part of the next century, so that during the next two centuries its motion

* Evolution of the Stellar Systems Vol. I.

will be very slow. Consequently observations for many years to come will probably not add much to our present knowledge of this pair. In 1825 a third star C was observed by Sir J. South at a distance of about 40″ from the principal star; this distance has increased to more than 60″ but the difference is satisfactorily accounted for by the proper motion of the system. The magnitudes of the components A and B and of the third star C are about 4.5, 5.0 and 10.2 respectively.

The data of the problem, p and s, for A aud B corresponding to the dates of observations of C, as shown in Table I, were read off from the position angle and distance curves as shown in the accompanying cut.

In constructing these curves I have used time as argument and the position angles and distances respectively as ordinates. The data which I used are indicated in connection with the construction. In the distance curve there is a suggestion of an undulation, covering a period of about 25 years.

The observations of A, B and A, C have been reduced to the equinox of 1850.

TABLE I.

Adopted Coördinates A, C.

Date.	Nights.	θ ° ′	ρ ″	Weight.	Observer.	Reference.
1837.09	5	89 24.0	43.95	1	Σ	*b*2
40.58	2	89 20.5	45.22	1	"	"
51.55	11	88 58.3	47.88	1	0Σ	"
55.52	7	88 44.6	49.06	1	"	"
60.26	7	88 26.7	50.28	1	"	"
64.31	4	88 14.5	51.52	1	Δ	*j*
66.91	4	88 12.0	52.32	1	0Σ	*b*2
75.04	2	87 49.0	54.84	1	Δ	*j*
75.64	5	87 36.4	54.56	1	0Σ	*b*2
82.51	3	87 16.0	56.22	1	"	"
1902.63	3	86 14.0	61.85	1	C	*o*

From the above data observation equations were formed for determining the five unknowns in equations (3). These treated by the method of least squares furnish the following elimination equations:

In Declination.	In Right Ascension.
$x + 0.000\,y - 0.713\,z - 0.024 = 0$	$x' + 0.000\,y' - 0.365\,z' - 0.161 = 0$
$y - 0.430\,z - 0.054 = 0$	$y' - 0.411\,z' + 0.007 = 0$
$z - 0.007 = 0$	$z' - 0.106 = 0$

in which

$$x = \Delta\alpha, \quad y = 37.90\,\Delta\beta, \quad z = 3.64\,\Delta k$$
$$x' = \Delta\mu, \quad y' = 37.90\,\Delta\nu, \quad z' = 2.45\,\Delta k,$$

Their solution yields

$$\Delta\alpha = -0.018, \quad \Delta\beta = +0.0015, \quad \Delta k = +0.002$$
$$\Delta\mu = +0.200, \quad \Delta\nu = +0.0009, \quad \Delta k = +0.043,$$

The assumed values were

$$\alpha_0 = +\ 3.055, \qquad \beta_0 = +\ 0.0745, \qquad k_0 = +\ 0.50$$
$$\mu_0 = +\ 51.677, \qquad \nu_0 = +\ 0.2973,$$

Therefore,

$$\alpha = +\ 3''.037 \pm 0''.3078 \qquad \mu = +\ 51''.877 \pm 0''.155$$
$$\beta = +\ 0''.0760 \pm 0''.0100 \qquad \nu = +\ 0''.2983 \pm 0''.0347$$
$$k = +\ 0\ .502 \pm 0\ .064 \qquad k = +\ 0\ .543 \pm 0\ .068$$

I find for the probable error of an equation of unit weight

In Declination $r_1 = \pm\ 0.10$. In Right Ascension $r_1 = \pm\ 0.23$.

The weights of the various quantities are

$P_x = 0.105$, $P_y = 0.262$, $P_z = 0.054$, $P_{x'} = 2.217$, $P_{y'} = 1.170$, $P_{z'} = 0.369$
$P_\alpha = 0.105$, $P_\beta = 9.937$, $P_k = 0.197$, $P_\mu = 2.217$, $P_\nu = 44.340$, $P_k = 0.904$

I then found the probable errors of α, β, μ, ν and k, as given above. The same arrangement is followed in the case of the other stars treated in this paper.

As a result of this investigation I find for the mean value of k,

$$k = +\ 0.52 \pm 0.065$$

which is accepted as the best the data will yield. This value is physically possible since from the nature of a center of gravity it must lie between the two bodies, from which it follows that k must lie between 0 and + 1 in order that it may have a physical interpretation. The result from the solution of such a set of equations is not subject to such limitations but might be equally well either positive or negative.

The time unit employed is one year and β and ν therefore represent annual variations. The values of α and μ given above are for the epoch 1864.73.

I have formed the sums of the squares of the residuals and found the probable error of an equation of unit weight on the hypothesis that $k = 0$ and $k = +\ 0.52$ as follows:

In Declination.

For $k = 0$ $[pvv] = 13.08$ $r_1 = \pm\ 1.28$
$k = +\ 0.52$ $[pvv] = 0.10$ $r_1 = \pm\ 0.11$

In Right Ascension.

For $k = 0$ $[pvv] = 1.01$ $r_1 = \pm\ 0.36$
$k = 0.52$ $[pvv] = 0.43$ $r_1 = \pm\ 0.24$

These results show a decided improvement due to assuming an orbital motion for A. Using the mean value of k, I find for the ratio of the masses of the components of σ Coronæ

$$A : B \quad 1 : 1.08$$

III.

Determination of the Relative Masses in the System β Delphini.

$\alpha = 20^h\ 31^m.9$ $\beta = +\ 14°\ 11'$

This close pair was discovered by Burnham in 1883. Since that time the components of the binary have described more than a revolution around their common center of gravity, and although their maximum distance is less than two-thirds of a second of arc and their minimum less than one-fourth of a second, the star has been well observed during the last twenty years.

The magnitudes of A and B are 4.3 and 5.9 respectively. There is a neighboring star C of the 12.7 magnitude which was observed by Sir John Herschel in 1828. It was measured by Burnham in 1878 and seven other observations of it are recorded up to 1898. These observations are shown in Table II. The corrections have been applied for reducing the distances, ρ, and the position angles, θ, from $\frac{AB}{2}$ to A as origin and for the reduction of the position angles, θ, to the equinox of 1900. The data, p and s, of B with respect to A were derived for the dates of the available observations of C from Burnham's* orbit and period of 26.7 years.

TABLE II.

Adopted Coördinates of A, C.

Date.	Nights.	θ °	′	ρ ″	Weights.	Observer.	Reference.
1878.05	3	115	51	27.71	1	β	1
81.19	4	115	42	27.68	1	"	"
83.54	1	116	31	27.50	.5	"	"
89.82	2	115	37	26.61	1	"	"
90.46	3	117	6	26.71	1	"	"
95.81	1	117	15	25.96	.5	L	"
98.49	3	117	12	25.63	1	β	"
98.59	2	116	47	25.68	1	Ba	"

From the data thus obtained observation equations were formed for determining the five unknowns in equations (3). These treated by the method of least squares yielded the following elimination equations.

In Declination.

$$x - 0.004\,y + 0.286\,z - 0.012 = 0$$
$$y + 0.380\,z + 0.143 = 0$$
$$z + 0.387 = 0$$

In Right Ascension.

$$x' - 0.004\,y - 0.020\,z - 0.117 = 0$$
$$y - 0.121\,z + 0.139 = 0$$
$$z + 0.681 = 0$$

in which

$$x = \Delta\alpha, \quad y = 11.32\,\Delta\beta, \quad z = \Delta k,$$
$$x' = \Delta\mu, \quad y' = 11.32\,\Delta\nu, \quad z' = \Delta k,$$

Their solution yields

$$\Delta\alpha = +0.123, \quad \Delta\beta = +0\ 00035, \quad \Delta k = -0.387,$$
$$\Delta\mu = -0.028, \quad \Delta\nu = -0.01952, \quad \Delta k = -0.681,$$

The assumed values were

$$\alpha_0 = -12.036, \quad \beta_0 = +0.1582, \quad k_0 = +0.50$$
$$\mu_0 = +23.776, \quad \nu_0 = -0.09226,$$

* *Pub. Yerkes Observatory* Vol. I.

Therefore,

$\alpha = -11''.913 \pm 0''.181$ $\mu = +23''.748 \pm 0''.063$
$\beta = +0''.01582 \pm 0''.00878$ $\nu = -0''.11178 \pm 0''.0255$
$k = +0.113 \pm 1.04$ $k = -0.181 \pm 2.65$

I find for the probable error of an equation of unit weight

In Declination $r_1 = \pm 0.26$ In Right Ascension $r_1 = \pm 0.21$

The weights of the various quantities are

$P_x = 2.06$, $P_y = 2.69$, $P_z = 0.274$, $P_{x'} = 6.983$, $P_{y'} = 2.446$, $P_{z'} = 0.163$,
$P_\alpha = 2.06$, $P_\beta = 28.80$, $P_k = 0.274$, $P_\mu = 6.983$, $P_\nu = 27.69$, $P_k = 0.163$,

I then found the probable errors of α, β, μ, ν and k as given above.

The value of k derived from the right ascension equations is physically impossible, and the large probable errors show that both values of k are wholly unreliable.

Another companion, D, of the eleventh magnitude was observed by William Struve in 1829. This has been fairly well observed in subsequent years and in this investigation eighteen observations of $\frac{AB}{2}$, D, as shown in the following table have been used. The data, p and s, of B with respect to A were derived for the dates of the available observations of D, from Burnham's orbit as referred to above.

Corrections have been applied for reducing the distances, ρ, and position angles, θ, from $\frac{AB}{2}$ to A as origin and for the reduction of the position angles, θ, to the equinox of 1900.

TABLE III.

Adopted Coördinates A, D.

Date.	Nights.	θ ° ′	ρ ″	Weights.	Observer.	Reference.
1829.40	3	343 27	32.32	1	Σ	1
51.84	2	339 16	33.80	1	0Σ	"
64.61	2	336 25	34.83	1	Δ	*i*
65.60	1	336 38	34.85	1	"	"
73.75	1	336 7	35.29	1	"	"
76.85	1	334 48	35.48	1	0Σ	*b*2
77.66	2	335 22	36.29	1	Sp	*n*
77.77	1	336 00	35.63	1	Δ	*i*
80.49	5	334 46	35.34	1	β	*f*
83.54	1	334 3	35.37	1	"	"
88.82	2	333 3	36.50	1	"	1
95.81	2	331 15	36.95	1	L	*j*
96.63	1	333 8	37.52	1	Pr	*q*
98.49	3	331 37	37.46	1	β	1
98.71	1	332 32	37.26	1	Ba	"
98.75	1	333 32	37.60	1	L	*j*
1901.83	1	330 37	37.90	1	"	"
02.81	3	331 26	36.98	1	C	*o*

From the data thus obtained I formed observation equations for determining the five unknowns in equations (3).

These treated by the method of least squares yielded the following elimination equations:

In Declination.	In Right Ascension.
$x + 0.000\,y + 0.383\,z - 0.378 = 0$	$x' + 0.000\,y' + 0.047\,z' + 0.425 = 0$
$y + 0.492\,z - 0.225 = 0$	$y' - 0.030\,z' + 0.575 = 0$
$z + 0.307 = 0$	$z' + 0.430 = 0$

in which

$$x = \Delta\alpha, \quad y = 51.898\,\Delta\beta, \quad z = \Delta k,$$
$$x' = \Delta\mu, \quad y' = 51.898\,\Delta\nu, \quad z' = \Delta k,$$

Their solution yields

$$\Delta\alpha = +0.490, \quad \Delta\beta = +0.0072, \quad \Delta k = -0.307$$
$$\Delta\mu = -0.4049, \quad \Delta\nu = -0.0113, \quad \Delta k = -0.430$$

The assumed values were

$$\alpha_0 = +14.782, \quad \beta_0 = +0.1047, \quad k_0 = +0.50,$$
$$\mu_0 = -32.115, \quad \nu_0 = -0.0214$$

Therefore,

$$\alpha = +15''.272 \pm 0''.193 \qquad \mu = -32''.520 \pm 0''.161$$
$$\beta = +0''.1119 \pm 0''.0508 \qquad \nu = -0''.0327 \pm 0''.0447$$
$$k = +0.193 \pm 0.884 \qquad k = +0.070 \pm 1.544$$

I find for the probable error of an equation of unit weight

In Declination $r_1 = \pm 0.46$. In Right Ascension $r_1 = \pm 0.50$.

The weights of the various quantities are as follows:

$$P_x = 5.58, \quad P_y = 1.56, \quad P_z = 1.07, \quad P_{x'} = 16.54, \quad P_{y'} = 2.40, \quad P_{z'} = 0.44$$
$$P_\alpha = 5.58, \quad P_\beta = 80.83, \quad P_k = 1.07, \quad P_\mu = 16.54, \quad P_\nu = 124.33, \quad P_{k'} = 0.44$$

The large probable errors in the values of k show that these values are wholly unreliable, on the other hand the values obtained for α, β, μ and ν are valuable results. The values of α and μ are for the epoch 1881.30.

(To be Concluded in June-July No.)

PLANET NOTES FOR JUNE, 1905.

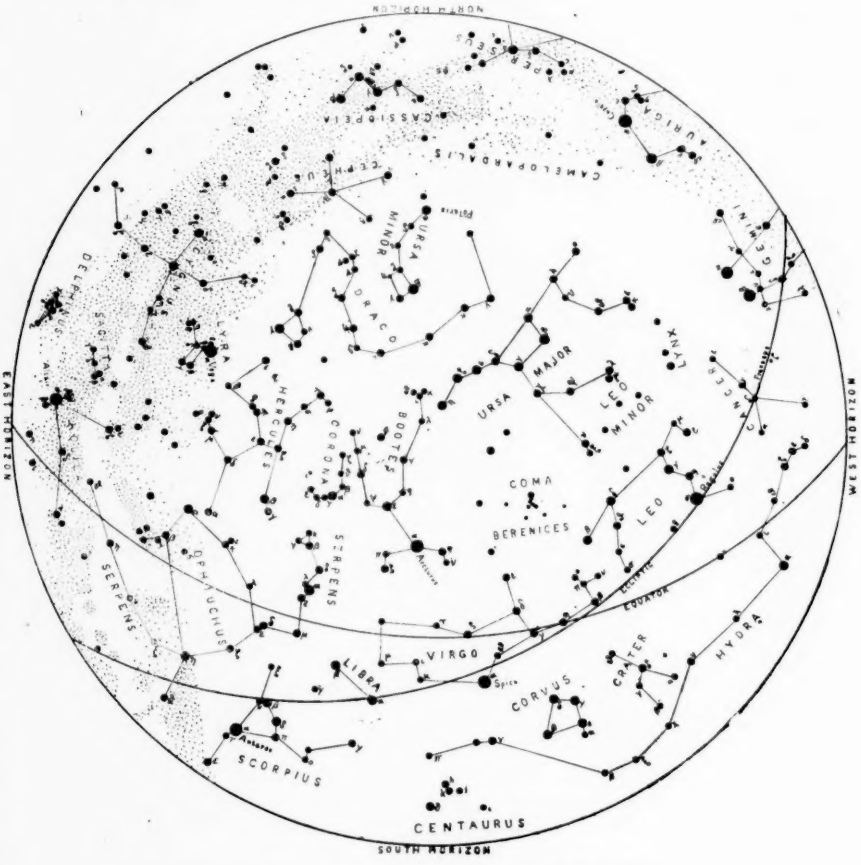
H. C. WILSON.

Mercury will be morning star, but invisible to the naked eye during the first three weeks of June. The planet is passing around to the farther side of the Sun and will be at superior conjunction on the morning of June 24.

Venus will be very brilliant as morning star during June and may be seen toward the east for a couple of hours before sunrise. The crescent phase will increase from 0.257 on June 1 to 0.470 on July 1; her appearance in the telescope will be that of the Moon to the naked eye when it is from four to seven days old.

Mars, having passed opposition in May, will be in fairly good position for evening observation during June. The planet is near the meridian, in the constellation Libra at about ten o'clock on June 1 and eight o'clock on June 30. The apparent diameter of the planet as seen with a telescope will be 18″ June 1 and 15″ June 30, so that with telescopes which allow the use of moderately high magnifying powers and under good atmospheric conditions the surface markings of the planet ought to be well seen. On June 17 Mars will be stationary in right ascension, having reached the west end of the loop in its apparent path (see diagram in January number of *P. A.* page), and after that time the motion will be eastward.

Jupiter is morning star, having been at superior conjunction May 3. During the last days of the month Jupiter and Venus will be quite near each other and we shall have repeated in the morning sky the spectacle of the two brilliant planets close together, which has been so notable in the western evening sky during March.



THE CONSTELLATIONS AT 9 P. M. June 1, 1905.

Saturn may be observed in the morning in the constellation Aquarius, being near the meridian at six o'clock, June 1, and at four o'clock, June 30.

Uranus may be observed, with the aid of a telescope at about midnight. The planet will be at opposition on the morning of June 24. It is in a bright part of the Milky Way in the constellation Sagittarius, and its position June 15 will be: R. A. $18^h\ 11^m\ 24^s$; Decl. $-23°\ 41'$.

Neptune will be at superior conjunction June 29 and so is not in good position for observation during this month.

Occultations Visible at Washington.

Date. 1905.	Star's Name.	Magnitude.	IMMERSION. Washington M.T.	IMMERSION. Angle from N pt.	EMERSION. Washington M. T.	EMERSION. Angle from N pt.	Duration.
			h m	°	h m	°	h m
June 14	γ Libræ	4.1	6 23	109	7 31	294	1 08
14	η Libræ	5.5	11 36	138	12 40	251	1 04
15	24 Scorpii	5.0	10 12	40	10 48	348	0 36
18	Mayer 814	6.1	8 26	68	9 24	294	0 58
22	h^1 Aquarii	5.4	10 08	67	11 5	265	0 57

COMET AND ASTEROID NOTES.

Comet Giacobini (a 1905.)—A cable message received March 27, from Dr. Kreutz, of Kiel, via Harvard College Observatory, announced the discovery of a faint comet by Giacobini, at Nice, and on the following day a second position was communicated through the courtesy of the Director of Lick Observatory, having been secured there by Mr. Aitken. These positions are here given.

Positions

Greenwich M. T. 1905	R. A. h m s	Decl. ° ′ ″	Observer.
March 26.3213	5 44 14.0	+10 56 56	Giacobini
27.6692	5 48 54.8	+12 35 43	Aitken

The following elements and ephemeris have kindly been communicated by telegraph by Admiral Chester, Director of the U. S. Naval Observatory, being computed by Morgan and Lamson, from observations of March 26, 27 and 28.

Elements.

$T = 1905$ April 3.57 Greenwich M. T.
$\omega = 357°\ 13'$
$\Omega = 154\ \ 8$ } Mean Eq. 1905.0
$i = 42\ \ 59$
$q = 1.1507$

Ephemeris.

Gr. Midnight 1905	R.A. h m s	Decl. ° ′	Light
April 1	6 6 4	+18 14	1.00
5	6 21 28	22 45	
9	6 37 56	27 2	
13	6 55 52	+31 0	.88

Light March 26 = 1.

Science Observer, *Special Circular No. 138*

Elements and Ephemeris of Comet a 1905 Giacobini.—The elements were derived from the following observations which were received by telegraph:

1905 Gr. M. T.	Comet's Apparent α h m s	δ ° ′ ″	Observer.
March 26.3212	5 44 14.0	+10 56 56	Giacobini (Nice)
27.6692	5 48 54.8	+12 35 43	Aitken (Mt. Hamilton, Cal.)
30.7185	2 59 59.5	+16 19 11	Aitken

The orbit was computed by a method (as yet unpublished) of Professor Leuschner, which is an adaption of his Short Method* to the direct computation of a parabola.

*Publications of the *Lick Observatory*, Vol. VII, Part 1.

The residuals for the first and third places are:

	$\Delta\alpha \cos\delta$	$\Delta\delta$
	s	′
I	± 0.0	+ 0.04
III	− 0.1	+ 0.04

The residuals for an observation of March 31 made by Aitken are:

+ 0.4 + 0.12

ELEMENTS.

$T = 1905$ April 3.7312 Greenwich M. T.
$\omega = 357° 49'.6$
$\Omega = 156\ 45\ .5$ 1905.0
$i = 40\ 51\ .4$
$\log q = 0.04981$

CONSTANTS FOR THE EQUATOR 1905.0.

$x = r\ [9.98503] \sin (249° 49'.9 + v)$
$y = r\ [9.98594] \sin (155 52\ .1 + v)$
$z = r\ [9.55588] \sin (23 43\ .0 + v)$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1905	True α	True δ	log Δ	Br.
	h m s	° ′		
April 3.5	6 14 46	+ 20 53.1	9.8524	1.00
7.5	31 35	25 32.9	9.8570	
11.5	6 49 44	29 56.7	9.8647	
15.5	7 06 10	33 59.6	9.8752	0.72

Brightness March 26 = 1.00

R. T. CRAWFORD,
J. D. MADDRILL.

Lick Observatory Bulletin, No. 73.

Elements and Ephemeris of Comet *a* 1905 (Giacobini).

Eleanor A. Lamson.

[Communicated by Rear-Admiral Colby M. Chester U. S. N., Superintendent.]

The following elements were deduced from observations made at Washington March 28, March 31 and April 3.

ELEMENTS.

T = April 4.047834 G. M. Time.
$\omega = 358° 12' 25''.6$
$\Omega = 157\ 7\ 9\ .9$ Mean Eq. 1905.0
$i = 40\ 23\ 51\ .9$
$q = 1.117841$

Residuals (O—C): $\cos\beta\,\Delta\lambda = + 5.3''$, $\Delta\beta = - 0.''3$

CONSTANTS TO THE EQUATOR.

$x = r\ [9.985755] \sin (250° 23' 24''.2 + v)$
$y = r\ [9.986593] \sin (156 37 20\ .4 + v)$
$z = r\ [9.545604] \sin (24 20 44\ .7 + v)$

EPHEMERIS.

G. M. T. 1905.	α h m s	δ ° ′ ″	Light.
April 28.5	8 21 32.5	+ 44 12 43	0.84
May 2.5	8 45 33.5	46 15 59	0.75
6.5	9 9 54.5	47 49 34	0.66
10.5	9 34 12.4	48 55 9	0.57
14.5	9 58 4.8	49 35 6	0.50
18.5	10 21 11.1	49 52 8	0.44
22.5	10 43 16.2	49 49 9	0.38
26.5	11 4 9.9	49 28 57	0.34
May 30.5	11 23 47.1	+ 48 54 18	0.29

Brightness March 29, unity.

Corr. to Ephemeris April 8, $\Delta\alpha = + 0.^s2$, $\Delta\delta = + 3''$.

The Orbit of the New Comet *a* 1905.—From the elements computed by Miss Lamson, given above, we have prepared the accompanying diagram, which will show the relative positions of the comet and the Earth. It will be seen that the comet at its perihelion approached within approximately 12,000,000 miles of the Earth's path, but that the Earth had passed the point of greatest proximity of the orbits about a month earlier, so that the approach was by no

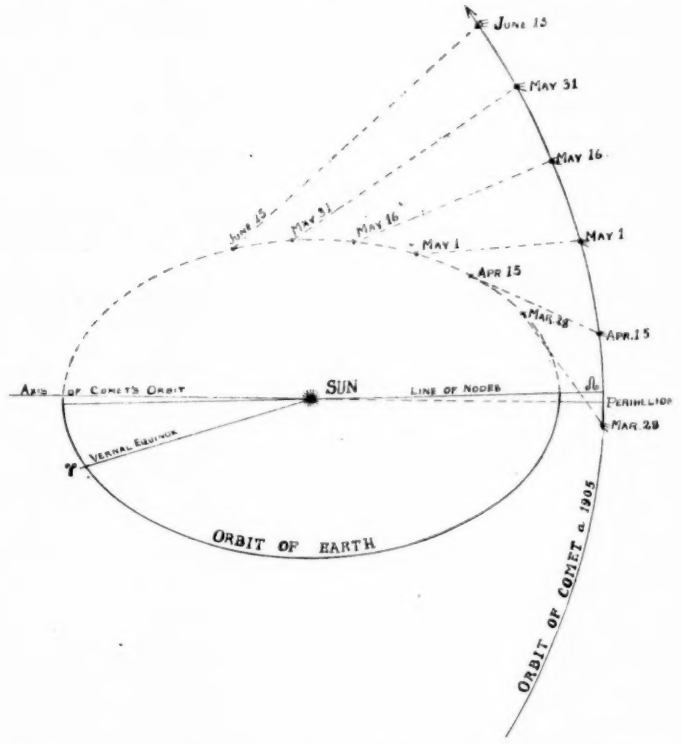


DIAGRAM OF THE ORBIT OF COMET *a* 1905, DISCOVERED BY GIACOBINI MARCH 28, 1905.

means as close as it might have been. It will be seen also that the Earth has all this time been moving away from the comet so that there is no chance of the comet's becoming a bright object. Miss Lamson's ephemeris shows that the brightness of the comet on May 30 will be only three-tenths of that which it possessed at the time of discovery, and it was then a faint telescopic object. Its course has been northeasterly through Orion, Gemini and Lynx; and during May it will be passing through the southern part of Ursa Major.

Search Ephemeris for Tempel's Periodic Comet (1867 II).—In *A. N.* 4008 Mr. R. Gautier, of the Observatory at Geneva, Switzerland, gives a search ephemeris for this comet extending from March 31 to July 13, 1905. The

comet has not been observed since its second return to perihelion in 1879, and therefore its detection is quite uncertain this year. Its position will be about as favorable as possible, the comet being at perihelion and near opposition at the same time, about April 20. The following are the elements adopted by Mr. Gautier for 1905.

$T = 1905$ April 20.5, Berlin M. T.
$\omega = 168°\ 40.'3$
$\Omega = 72\ 41.7$ } 1905.0
$i = 10\ 47.2$
$\phi = 23\ 42.0$
$\mu = 542.''68$

From the following ephemerides it will appear that the comet is most favorably situated for observers in the southern hemisphere, and that its path lies in the region about the foot of Ophiuchus, between Scorpio and Sagittarius. Mr. Gautier has computed three ephemerides, with the dates of perihelion passage May 2.5, April 20.5 and April 8.5 respectively. It is to be hoped that a very careful search will be made both with the great telescopes and with the photographic star-cameras which are now doing such wonderful work.

SEARCH EPHEMERIS FOR COMET TEMPEL1 (1867 II).

Perihelion April 20.5.

Date.	R. A.			Decl.		log r	log Δ
	h	m	s	°	′		
May 2	17	40	58	−21	16.5	0.3208	0.0952
4		41	10	21	29.8		
6		41	13	21	43.4	0.3211	0.0857
8		41	8	21	57.3		
10		40	56	22	11.4	0.3215	0.0768
12		40	36	22	25.8		
14		40	8	22	40.4	0.3220	0.0688
16		39	33	22	55.2		
18		38	50	23	10.3	0.3226	0.0619
20		38	0	23	25.5		
22		37	4	23	40.9	0.3233	0.0560
24		36	1	23	56.4		
26		34	52	24	11.9	0.3240	0.0513
28		33	38	24	27.5		
30		32	18	24	43.0	0.3248	0.0479
June 1		30	54	24	58.5		
3		29	26	25	13 9	0.3258	0.0460
5		27	55	25	29.1		
7		26	22	25	44.2	0.3268	0.0454
9		24	47	25	59.0		
11		23	11	26	13.5	0.3278	0.0464
13		21	35	26	27.7		
15		19	59	26	41.6	0.3290	0.0488
17		18	25	26	55.2		
19		16	52	27	8.4	0.3302	0.0526
21		15	21	27	21.2		
23		13	54	27	33.7	0.3315	0.0578
25		12	30	27	45.7		
27		11	11	27	57.3	0.3329	0.0644
29		9	57	28	8.5		
July 1		8	48	28	19.3	0.3344	0.0721
3		7	45	28	29.6		
5		6	49	28	39.6	0.3359	0.0809
7		5	59	28	49.2		
9		5	16	28	58.4	0.3375	0.0907
11		4	41	29	7.3		
13	17	4	13	−29	15.8	0.3391	0.1014

SEARCH EPHEMERIDES FOR COMET TEMPEL1 (1867 II).

Date.	Perihelion May 2.5 R. A.	Decl.	Perihelion April 8.5 R. A.	Decl.
	h m s	° ′	h m s	° ′
May 2	17 9 55	−19 14.6	18 10 31	−22 48.1
4	9 38	19 27.0	11 12	23 1.4
6	9 13	19 39.7	11 44	23 15.1
8	8 41	19 52.6	12 9	23 29.1
10	8 1	20 5.8	12 25	23 43.5
12	7 14	20 19.2	12 33	23 58.2
14	6 20	20 32.9	12 33	24 13.3
16	5 20	20 46.7	12 25	24 28.6
18	4 14	21 0.7	12 9	24 44.1
20	3 2	21 14.8	11 45	24 59.9
22	1 45	21 28.9	11 13	25 16.0
24	17 0 24	21 43.1	10 34	25 32.2
26	16 58 58	21 57.4	9 48	25 48.5
28	57 29	22 11.7	8 54	26 5.0
30	55 57	22 26.0	7 53	26 21.5
June 1	54 23	22 40.2	6 46	26 38.0
3	52 48	22 54.3	5 34	26 54.5
5	51 12	23 8.3	4 16	27 10.9
7	49 37	23 22.2	2 54	27 27.1
9	48 2	23 35.9	18 1 28	27 43.1
11	46 29	23 49.4	17 59 58	27 58.9
13	44 58	24 2.8	58 25	28 14.4
15	43 30	24 15.9	56 50	28 29.5
17	42 5	24 28.8	55 14	28 44.2
19	40 45	24 41.5	53 37	28 58.5
21	39 30	24 53.9	52 0	29 12.4
23	38 19	25 6.1	50 24	29 25.9
25	37 14	25 18.1	48 49	29 38.8
27	36 14	25 29.8	47 16	29 51.2
29	35 21	25 41.3	45 46	30 2.2
July 1	34 35	25 52.5	44 20	30 13.1
3	33 56	26 3.6	42 57	30 24.1
5	33 24	26 14.4	41 39	30 35.1
7	33 0	26 25.0	40 26	30 46.1
9	32 44	26 35 4	39 19	30 57.0
11	32 35	26 45.6	38 18	31 7.9
13	16 32 36	−26 55.6	17 37 24	−31 18.8

New Asteroids.—The following have been added to the list of new minor planets since our last note:

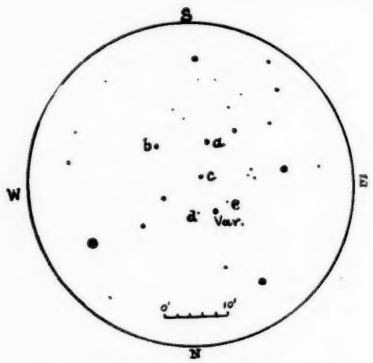
	Discovered by	at	Local Mean Time.	R. A. h m	Decl. ° ′	Mag.
1905 QD	Wolf	Heidelberg	1905 Mar. 8 11 19	13 08.7	+ 7 32	12.5
QE	Götz	"	13 13 45	12 46.6	+ 0 05	12.5
QF	Wolf	"	13 14 13	11 05.4	+18 56	12.2
QG	Wolf	"	26 10 47	12 26.2	− 1 48	13.5

VARIABLE STARS.

New Variables in the Vicinity of δ Aquilæ.—In *A. N.* 4005 Messrs. M. and G. Wolf give a list of thirty-six new variables, found upon photographs of the region around δ Aquilæ. These have been assigned the numbers 2-37. 1905. All of them are very faint stars, only a few reaching the brightness of 10th magnitude, thirty-two charts showing the stars in the vicinity of the variables accompany the paper.

New Variable 38.1905 Andromedæ.—This is announced by Mr. A. Stanley Williams in *A. N.* 4005. The position is

1855.0	R.A.	0^h	56^m	$26.^s5$;	Decl.	$+40°$	$31.'6$
1900.0		0	58	54.5		+40	46.2



VICINITY OF THE VARIABLE STAR 38.1905 ANDROMEDÆ.

The maximum brightness of the star is $10^m.5$ and the minimum $11^m.8$, the period being 45.2 days. From twelve photographs Mr. Williams derives the following elements:

Maximum = 1899 Nov. 12 (J. D. 2414971) + $45^d.2$ E.

In the accompanying chart the stars marked *b*, *c*, *d*, *e* were assumed to be of the magnitudes 10.0, 10.9, 10.9 and 11.3 respectively.

New Variable Star 41.1905 Cassiopeiæ.—In *A. N.* 4001 Professor W. Ceraski calls attention to a star which has been found on one photograph taken at Moscow Oct. 31, 1904, to be of the ninth magnitude while on five other photographs of the same region, taken Aug. 12, 15, 18, Sept. 18, 1904 and Feb. 13, 1905, it is either invisible or below the twelfth magnitude. The position of the star is

1855.0	R. A.	0^h	44^m	35^s	Decl.	$+46°$	$38'.1$
1900.0		0	47	06		+46	52 .8

New Variable 42.1905 Monocerotis.—In *A. N.* 4001 Mr. Thomas D. Anderson announces as variable the star BD. —10°, 2396, whose position for 1855.0 is R.A. 8^h 01^m $49.^s1$; Decl. — 10° 22′.7. On Jan. 18 it was estimated as $8^m.5$ and on Feb. 22 as $9^m.3$, while the neighboring stars BD. —11°, 2262, — 10°, 2395 and — 10°, 2401 were estimated at $8^m.4$, $8^m.9$ and $9^m.5$ respectively.

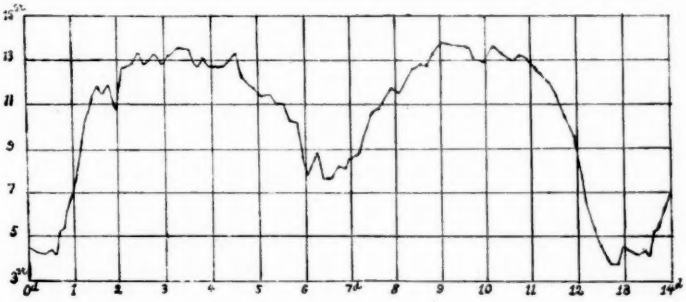
New Variable 43.1905 Monocerotis.—This is announced in *A. N.* 4003 by Professor Ceraski, and is BD. —7°, 1623. Its position is

1855.0	R.A.	6^h	47^m	$13^s.0$;	Decl.	$-7°$	$25'.1$
1900.0		6	49	23 .6		— 7	28 .2

In February 1902, on a photographic plate taken by M. S. Blajko on March 15, 1901, 8^h 48^m —10^h 38^m, Moscow M. T., Mme. L. Ceraski found the star to be about a half magnitude fainter than on other plates. Whenever examined

since then it has been of nearly its usual brightness ($9^m.8$) until Feb. 23, 1905, from $7^h\ 40^m$ to $12^h\ 0^m$ Moscow mean time, when a minimum was observed and on the next night the increase of brightness after minimum. The star appears to be at about $10^m.5$ at minimum, the change in brightness lasts six or seven hours and the minima follow each other at intervals of about 21.8 hours. It is probably of the Algol type.

β Lyræ.—In *A. N.* 4005 Mr. S. Beliawsky, a student in the University of St. Petersburg, gives a light-curve of this variable star based upon his reduction



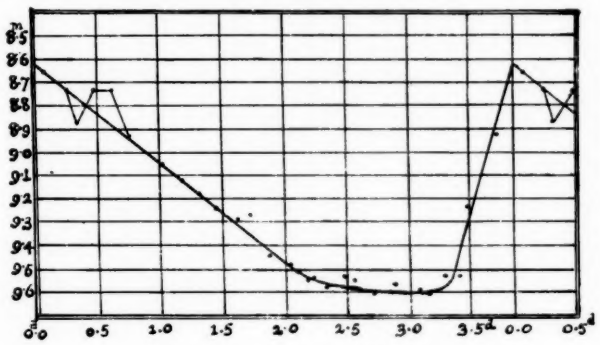
THE LIGHT CURVE OF β LYRÆ.

of the observations made by Professor Glasenapp during the ten years 1892-1902. The curve is in general like those which have been previously published but presents some minor differences.

Missing Stars.—Mr. J. Guillaume states, in *A. N.* 4005, that the star BD. + 17°, 344 $9^m.5$, R. A. (1855)= $2^h\ 12^m\ 29^s.0$; Decl. + 17° 50′.8, was missing from the sky on Feb. 4, 6, 8 and 9, 1905.

Mr. Ludendorff also, in *A. N.* 4006, calls attention to the star BD. + 37°, 855, $9^m.5$ R. A. (1855) $3^h\ 51^m\ 0^s.49$; Decl. + 37° 35′.5, which he finds to be missing from photographs taken Nov. 26, 1896, and Oct. 16, 1899.

Variable Star Y Aurigæ.—The *Monthly Notices* of the Royal Astronomical Society, England, for January 1905, contains an excellent paper by Mr.



THE LIGHT CURUE OF Y AURIGÆ.

A. Stanley Williams on the Variable Star Y Aurigæ, in which he gives a determination of the elements of the light variation of the star from a long series of observations by himself, extending from Feb. 6, 1901 to Apr. 20, 1904. Ac-

cording to the light-curve the star wanes steadily for about two days and a quarter, is almost at a stand still at minimum for a day, then rises to maximum in a little over half a day, remaining at maximum for only a very small fraction of a day. The total period of the variation is 3.8590 days or $3^d\ 20^h\ 36^m\ 58^s$, the formula for the maximum being

$$\text{Maximum} = \text{J. D. } 2415420.64 + 3^d.8590\ E.$$

The brightness at maximum is $8^m.6$ and at minimum $9^m.6$. Mr. Williams gives the following list of comparison stars:

Star.	Name.	BD. Mag.	Adopted Mag.
h	BD. + 42 1291	8.2	8.19
l	+ 42 1305	9.0	8.47
f	+ 42 1301	9.0	8.85
b	+ 42 1297	9.5	9.52
c	+ 42 1302	9.4	9.72

Approximate Magnitudes of Variable Stars Apr. 10, 1905.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	11.5 *s*	R Camelop.	14	25.1	+84	17	8.4 *i*
T Cassiop.	0	17.8	+55	14	8 *i*	R Bootis	14	32.8	+27	10	12
R Androm.	0	18.8	+38	1	6.7 *i*	S Librae	15	15.6	−20	2	11.5*d*
S Ceti	0	19.0	− 9	53	*f s*	S Serpentis	15	17.0	+14	40	*u*
S Cassiop.	1	12.3	+72	5	9.0*d*	S Coronae	15	17.3	+31	44	7.0 *i*
R Piscium	1	25.5	+ 2	22	*f s*	S Urs. Min.	15	33.4	+78	58	11 *d*
U Persei	1	52.9	+54	20	11 *d*	R Coronae	15	44.4	+28	28	6.4
R Arietis	2	10.4	+24	36	12.5*d*	V "	15	45.9	+39	52	8 *i*
o Ceti	2	14.3	− 3	26	5 *s*	R Serpentis	15	46.1	+15	26	13 *d*
S Persei	2	15.7	+58	8	8.5 *i*	R Herculis	16	1.7	+18	38	*f*
R Ceti	2	20.9	− 0	38	10 *s*	R Scorpii	16	11.7	−22	42	*f*
U "	2	28.9	−13	35	*s*	S "	16	11.7	−22	39	11 *i*
R Trianguli	2	31.0	+33	50	8 *i*	U Herculis	16	21.4	+19	7	7 *i*
R Persei	3	23.7	+35	20	13.5*d*	W Herculis	16	31.7	+38	32	*f*
R Tauri	4	22.8	+ 9	56	12.5*d*	R Draconis	16	32.4	+66	58	*f*
S "	4	23.7	+ 9	44	12. *d*	S Herculis	16	47.4	+15	7	*f*
R Aurigæ	5	9.2	+53	28	9. *d*	R Ophiuchi	17	2.0	−15	58	11.5 *i*
U Orionis	5	49.9	+20	10	7.5 *i*	T Herculis	18	5.3	+31	0	8 *i*
R Lyncis	6	53.0	+55	28	13 *d*	R Scuti	18	42.2	− 5	49	5.5
R Gemin.	7	1.3	+22	52	13.7*d*	R Aquilae	19	1.6	+ 8	5	6 *i*
S Canis Min.	7	27.3	+ 8	32	10.5*d*	R Sagittarii	19	10.8	−19	29	*f*
R Cancri	8	11.0	+12	2	10.6*d*	S "	19	13.6	−19	12	*u*
V "	8	16.0	+17	36	11.0*d*	R Cygni	19	34.1	+49	58	10.6*d*
S Hydrae	8	48.4	+ 3	27	10.5 *i*	RT "	19	40.8	+48	32	11.3 *i*
T "	8	50.8	− 8	46	12.5*d*	X "	19	46.7	+32	40	8.5*d*
R Leo. Min.	9	39.6	+34	58	11.5*d*	S "	20	3.4	+57	42	11.5 *i*
R Leonis	9	42.2	+11	54	7.0 *i*	RS "	20	9.8	+38	28	8 *d*
R Urs. Maj.	10	37.6	+69	18	7.5 *i*	R Delphini	20	10.1	+ 8	47	*u*
R Comae Ber.	11	59.1	+19	20	14.5 *f*	U Cygni	20	16.5	+47	35	10.3 *i*
T Virginis	12	9.5	− 5	29	12.5*d*	V "	20	38.1	+47	47	*f*
R Corvi	12	14.4	−18	42	11.7*d*	T Aquarii	20	44.7	− 5	31	*u*
Y Virginis	12	28.7	− 3	52	9.5 *i*	R Vulpec.	20	59.9	+23	26	*f*
T Urs. Maj.	12	31.8	+60	2	8.0*d*	T Cephei	21	8.2	+68	5	6.5 *i*
R Virginis	12	33.4	+ 7	32	6.7 *i*	S "	21	36.5	+78	10	9.8 *i*
S Urs. Maj.	12	39.6	+61	38	10.7*d*	S Lacertae	22	24.6	+39	48	9.5*d*
U Virginis	12	46.0	+ 6	6	12.5*d*	R "	22	38.8	+41	51	*u*
V "	13	22.6	− 2	39	10.0 *i*	S Aquarii	22	51.8	−20	53	*s*
R Hydrae	13	24.2	−22	46	4.2 *i*	R Pegasi	23	1.6	+10	0	*s*
S Virginis	13	27.8	− 6	41	12.3*d*	S "	23	15.5	+ 8	22	*s*
R Can. Ven.	13	44.6	+40	2	8.3 *i*	R Aquarii	23	38.6	+15	50	*s*
S Bootis	14	19.5	+54	16	8.5 *i*	R Cassiop.	23	53.3	+50	50	7 *i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that the light is increasing; *d*, that the light is decreasing; *s*, that it is near the Sun; and *u*, that its magnitude is unknown.

From observations made at the McCormick, Pereira, Vassar College, Mt. Holyoke College and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc.

U Cephei.

	d	h
June	2	7
	4	19
	7	7
	9	19
	12	6
	14	18
	17	6
	19	18
	22	6
	24	18
	27	5
	29	17

Z Persei.

June	3	1
	6	2
	9	4
	12	5
	15	6
	18	8
	21	9
	24	10
	27	12
	30	13

Algol.

June	2	22
	5	19
	8	16
	11	13
	14	10
	17	7
	20	3
	23	0
	25	21
	28	18

λ Tauri.

June	3	10
	7	9
	11	8
	15	6
	19	5
	23	4
	27	3

RT Persei.

June	1	15
	2	11
	3	8
	4	4
	5	0
	5	21
	6	17
	7	14
	8	10
	9	6
	10	3

RT Persei.

	d	h
June	10	23
	11	19
	12	16
	13	12
	14	9
	15	5
	16	1
	16	22
	17	18
	18	15
	19	11
	20	7
	21	4
	22	0
	22	20
	23	17
	24	13
	25	10
	26	6
	27	2
	27	23
	28	19
	29	16
	30	12

R Canis Maj.

June	1	9
	2	13
	3	16
	4	19
	5	22
	7	2
	8	5
	9	8
	10	11
	11	15
	12	18
	13	21
	15	1
	16	4
	17	7
	18	10
	19	14
	20	17
	21	20
	22	23
	24	3
	25	6
	26	9
	27	12
	28	16
	29	19
	30	22

Y Camelopard.

June	3	14
	6	21
	10	4

Y Camelopard.

	d	h
June	13	12
	16	19
	20	2
	23	10
	26	17
	30	0

RR Puppis.

June	5	7
	11	17
	18	4
	24	14

V Puppis.

June	2	7
	3	18
	5	5
	6	16
	8	3
	9	14
	11	1
	12	12
	13	22
	15	9
	16	20
	18	7
	19	18
	21	5
	22	16
	24	3
	25	14
	27	1
	28	11
	29	22

S Cancri.

June	4	3
	13	14
	23	2

S Antliæ.

Period $7^h\ 46^m.8$

June	1	23
	2	22
	3	21
	4	21
	5	20
	6	19
	7	19
	8	18
	9	18
	10	17
	11	16
	12	16
	13	15
	14	14
	15	14

S Antliæ.

	d	h
June	16	13
	17	12
	18	12
	19	11
	20	10
	21	10
	22	9
	23	8
	24	8
	25	7
	26	6
	27	6
	28	5
	29	4
	30	4

S Velorum.

June	5	23
	11	22
	17	20
	23	18
	29	16

W. Urs. Maj.

Period $4^h\ 0.^m2$

June 1-20 15^h

21-30 16

RR Velorum.

June	1	8
	3	4
	5	1
	6	21
	8	18
	10	14
	12	11
	14	7
	16	4
	18	0
	19	21
	21	17
	23	14
	25	10
	27	7
	29	3

Z Draconis.

June	1	16
	3	0
	4	9
	5	17
	7	2
	8	10
	9	12
	11	4
	12	12
	13	21

Z Draconis.

	d	h
June	15	5
	16	14
	17	23
	19	7
	20	16
	22	0
	23	9
	24	17
	26	2
	27	11
	28	19
	30	4

δ Libræ.

June	2	2
	4	9
	6	17
	9	1
	11	9
	13	17
	16	1
	18	9
	20	16
	23	0
	25	8
	27	16
	30	0

U Coronæ.

June	2	23
	6	10
	9	21
	13	8
	16	18
	20	5
	23	16
	27	3
	30	14

R Aræ.

June	1	22
	6	8
	10	18
	15	4
	19	15
	24	1
	28	11

U Ophiuchi.

June	1	12
	2	8
	3	4
	4	0
	4	20
	5	17
	6	13
	7	9
	8	5

Minima of Variable Stars of the Algol Type.—Continued.

U Ophiuchi.

	d	h
June	9	1
	9	21
	10	17
	11	14
	12	10
	13	6
	14	2
	14	22
	15	18
	16	14
	17	10
	18	7
	19	3
	19	23
	20	19
	21	15
	22	11
	23	7
	24	3
	25	0
	25	20
	26	16
	27	12
	28	8
	29	4
	30	0
	30	20

Z Herculis.

	d	h
June	2	6
	4	3
	6	6
	8	3
	10	6
	12	3
	14	6
	16	3
	18	6
	20	3
	22	5
	24	2
	26	5
	28	2
	30	5

RS Sagittarii.

	d	h
June	2	3
	4	13
	6	23
	9	9
	11	19
	14	5
	16	15
	19	1
	21	11
	23	21
	26	7
	28	17

V Serpentis.

	d	h
June	2	10
	5	21
	9	8
	12	19
	16	6
	19	17
	23	4
	26	14
	30	1

RX Herculis.

	d	h
June	1	17
	2	14
	3	11
	4	9
	5	6
	6	3
	7	1
	7	22
	8	19
	9	17
	10	14
	11	11
	12	9
	13	6
	14	3
	15	1
	15	22
	16	20

RX Herculis.

	d	h
June	17	17
	18	14
	19	12
	20	9
	21	6
	22	4
	23	1
	23	22
	24	20
	25	17
	26	14
	27	12
	28	9
	29	6
	30	4

RV Lyræ.

	d	h
June	3	14
	7	4
	10	18
	14	9
	17	23
	21	14
	25	4
	28	18

U Sagittæ.

	d	h
June	1	14
	4	23
	8	9
	11	18
	15	3
	18	12
	21	21
	25	6
	28	15

SY Cygni.

	d	h
June	2	3
	8	3
	14	4
	20	4
	26	4

WW Cygni.

	d	h
June	4	5
	10	21
	14	5
	17	12
	20	20
	24	3
	27	11
	30	19

SW Cygni.

	d	h
June	3	8
	7	22
	12	11
	17	1
	21	15
	26	5
	30	18

VW Cygni.

	d	h
June	9	8
	17	19
	26	5

UW Cygni.

	d	h
June	1	12
	4	22
	8	9
	11	20
	15	7
	18	18
	22	4
	25	15
	29	2

W Delphini.

	d	h
June	2	22
	8	18
	13	13
	18	8
	23	4
	27	4

Y Cygni.

	d	h
June	1	6
	2	15
	4	6
	5	15
	7	6
	8	15
	10	5
	11	15
	13	5
	14	15
	16	5
	17	15
	19	5
	20	15
	22	5
	23	15
	25	5
	26	15
	28	5
	29	15

VV Cygni.

	d	h
June	1	19
	3	7
	4	18
	6	6
	7	17
	9	4
	10	16
	12	3
	13	15
	15	2
	16	14
	18	1
	19	13
	21	0
	22	11
	23	23
	25	10
	26	22
	28	9
	29	21

UZ Cygni.

	d	h
June	30	3

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.				Minimum.		Maximum.	
	d	h	d	h			d	h	d	h
T Vulpeculae	June 1	2	June 2	11	V Velorum	June	3	17	4	16
β Lyræ	1	16	4	23	X Cygni		3	17	8	20
T Crucis	1	19	3	20	RV Scorpii		3	21	5	6
U Vulpeculae	2	3	4	6	SU Cygni		4	5	5	13
η Aquilae	2	13	4	22	X Sagittarii		4	10	7	7
V Carinæ	2	16	4	20	V Centauri		4	21	6	8
S Crucis	2	21	4	9	δ Cephei		4	22	6	7
T Monocerotis	3	1	8	23	T Velorum		5	7	6	16
R Triang. Austr.	3	3	4	3	U Aquilæ		5	8	7	12
S Triang. Austr.	3	11	5	13	T Vulpeculae		5	12	6	21
W Virginis	3	13	11	17	S Sagittae		5	18	9	4
R Crucis	3	15	5	0	W Sagittarii		5	19	8	19

Variable Stars of Short Period not of the Algol Type.—(Continued.)

	Maximum.		Minimum.			Maximum.		Minimum.	
	d	h	d	h		d	h	d	h
U Sagittarii	June 5	20	June 8	19	κ Pavonis	June 18	19	June 23	4
Y Sagittarii	5	23	8	1	T Vulpeculae	18	20	20	5
R Triang. Austr.	6	13	7	13	T Velorum	19	6	20	15
S Crucis	7	14	9	2	U Sagittarii	19	8	22	7
S Normae	7	20	12	5	U Aquilae	19	8	21	12
SU Cygni	8	1	9	9	SU Cygni	19	15	20	23
V Velorum	8	2	9	1	R Triang. Austr.	20	2	21	2
β Lyrae	8	3	11	5	X Cygni	20	2	25	5
VY Cygni	8	5	10	7	W Virginis	20	20	29	0
S Muscae	8	10	11	21	W Sagittarii	20	23	23	23
T Crucis	8	12	10	13	δ Cephei	21	0	21	9
V Carinæ	9	8	11	12	β Lyræ	21	1	24	3
R Crucis	9	11	10	20	R Crucis	21	3	22	12
η Aquilae	9	17	12	2	V Velorum	21	4	22	3
κ Pavonis	9	17	14	2	V Centauri	21	9	22	20
S Triang. Austr.	9	19	11	21	S Crucis	21	15	23	3
R Triang. Austr.	9	20	10	20	T Crucis	21	23	24	0
T Velorum	9	23	11	8	RV Scorpii	22	2	23	11
T Vulpeculae	9	23	11	8	S Triang. Austr.	22	10	24	12
RV Scorpii	9	23	11	8	S Sagittae	22	13	25	23
U Vulpeculae	10	3	12	6	V Carinae	22	18	24	22
δ Cephei	10	7	11	16	T Vulpeculae	23	6	24	15
V Centauri	10	9	11	20	Y Sagittarii	23	6	25	8
X Sagittarii	11	10	13	7	R Triang. Austr.	23	11	24	11
Y Sagittarii	11	17	13	19	SU Cygni	23	11	24	19
Y Ophiuchi	11	17	17	22	T Velorum	23	21	25	6
SU Cygni	11	22	13	6	VY Cygni	23	22	26	0
TX Cygni	12	1	17	4	η Aquilae	24	2	26	11
S Crucis	12	6	13	18	X Sagittarii	25	10	28	7
U Aquilae	12	8	14	12	V Velorum	25	13	26	12
V Velorum	12	11	13	10	U Sagittarii	26	1	29	0
U Sagittarii	12	14	15	13	U Vulpeculae	26	2	28	5
R Triang. Austr.	13	7	14	7	S Crucis	26	8	27	20
W Sagittarii	13	9	16	9	δ Cephei	26	9	27	18
S Sagittae	14	3	17	13	U Aquilae	26	10	28	14
T Vulpeculae	14	9	15	18	TX Cygni	26	18	31	21
T Velorum	14	14	15	23	V Centauri	26	20	28	7
β Lyræ	14	14	17	21	R Triang. Austr.	26	21	27	21
T Crucis	15	6	17	7	R Crucis	26	22	28	7
R Crucis	15	7	16	16	SU Cygni	27	7	28	15
δ Cephei	15	15	17	0	S Normae	27	8	31	17
SU Cygni	15	18	17	2	β Lyræ	27	12	30	23
V Centauri	15	21	17	8	Γ Vulpeculæ	27	17	29	1
RV Scorpii	16	0	17	9	S Muscae	27	18	31	5
VY Cygni	16	1	18	3	κ Pavonis	27	21	32	6
S Triang. Austr.	16	2	18	4	RV Scorpii	28	3	29	12
V Carinae	16	2	18	6	T Velorum	28	13	29	22
R Triang. Austr.	16	4	17	4	W Sagittarii	28	14	31	14
V Velorum	16	19	17	18	T Crucis	28	17	30	18
η Aquilae	16	21	19	6	S Triang. Austr.	28	18	30	20
S Crucis	16	23	18	11	Y Ophiuchi	28	20	35	1
Y Sagittarii	17	12	19	14	Y Sagittarii	29	1	31	3
S Normae	17	14	21	23	V Carinae	29	11	31	15
S Muscae	18	1	21	12	V Velorum	29	22	30	21
U Vulpeculae	18	3	20	6	T Monocerotis	30	1	37	23
X Sagittarii	18	10	21	7	S Sagittae	30	22	34	8

Maxima of Y Lyræ.

Period $12^h\ 03^m.9$. The minimum occurs $1^h\ 40^m$ before the maximum.

d	h	d	h	d	h	d	h
June 1-8	9	June 9-15	10	June 16-23	11	June 24-30	12

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum.

	d	h		d	h		d	h		d	h
June	1	7	June	9	3	June	17	0	June	24	20
	2	10		10	6		18	3		25	23
	3	13		11	9		19	6		27	2
	4	16		12	12		20	9		28	5
	5	19		13	15		21	12		29	8
	6	22		14	18		22	14		30	11
	8	1		15	21		23	17			

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
June	1	18	June	9	22	June	18	2	June	26	7
	2	18		10	23		19	3		27	7
	3	19		11	23		20	3		28	8
	4	19		13	0		21	4		29	8
	5	20		14	0		22	4		30	9
	6	20		15	1		23	5			
	7	21		16	1		24	6			
	8	21		17	2		25	6			

GENERAL NOTES.

Some of our readers may complain because we have some mathematical articles in this number. Will such please remember that for nearly a year we have published nothing so heavy as that which we now give. Our popular readers will also please remember, if they know the facts, that every prominent Observatory on this side of the Sea, and about one hundred abroad are paid subscribers to this publication. We must give such some light American mathematical reading to keep their appetites good.

Accurate Time Pieces.—Those who are interested in knowing how a great watch company secures precision in the make of its watches may learn how the Waltham Company does it by reading a fully illustrated article in the *Scientific American*, April 15, 1905. The mounting of their regulators, the Observatory with its Transit instrument, the temperature and barometric instruments, the chronograph and electrical instruments show the pains-taking accuracy which the company seeks to reach. We did not before know that it is now the custom of the Waltham Company to submit a percentage of its watches to the national physical laboratory at the Kew Observatory, London, an institution which accepts instruments of precision from applicants anywhere in the world, and after testing them makes its report. Eighty-six per cent of the watches submitted by this company have been passed in class A. It is said that 80 or 85 per cent is a common figure. This is a high grade for a machine made watch.

Washington Midnight Time Signal May 3, 1905.—Rear-Admiral C. M. Chester, Superintendent of the United States Naval Observatory gives notice by circular that a special series of midnight telegraphic time signals is to be sent out by the Naval Observatory on May 3, 1905. As at other times, the signals will begin at 11:55 P. M., Eastern Standard Time, which is the mean solar time of the 75th meridian west of Greenwich, and end at midnight.

This special time signal is sent out at the request of the American Railway Association, with the cordial approval of the Secretary of the Navy, in honor of the International Railway Congress which is to meet in Washington on the following day. Superintendent Chester hopes to obtain such complete voluntary

coöperation on the part of all telegraphic, cable and telephone companies, as to secure for the signal quick, accurate, and world-wide distribution as far as electricity will carry it. Goodsell Observatory will cordially coöperate in this the third of its kind recently given.

Astronomical Telegrams Direct from Harvard College Observatory.—Notice is hereby given that the coöperation between this Observatory and Mr. John Ritchie, Jr., has this day been terminated, and the authority of Mr. Ritchie to represent this Observatory in the transmission of astronomical telegrams, and in business relating thereto, has been withdrawn.

Telegrams announcing astronomical discoveries and observations will hereafter be sent to subscribers directly from the Observatory instead of through Mr. Ritchie as formerly.

Astronomers are requested to continue to telegraph announcements of discoveries and observations as heretofore. All telegrams should be addressed "Harvard College Observatory, Cambridge, Mass." All correspondence relating to telegrams should be addressed to the undersigned.

HARVARD COLLEGE OBSERVATORY. EDWARD C. PICKERING.
April 6, 1905. Director.

Elongations of Mercury in 1905.—The following table, prepared by Mr. Roberdeau Buchanan of the U. S. *Nautical Almanac* Office, will interest some of our readers in showing how the angle of greatest elongation varies and how much longer is the period of visibility of the planet at some elongations than at others. For example at the eastern elongation in July and August the planet will be over 15° out from the Sun for forty-five days, while at the eastern elongation in March and April the distance from the Sun exceeded 15° for only eighteen days.

ELONGATIONS OF MERCURY IN 1905.

1905.	Elongation.			1905.	Elongation.		
	°	′			°	′	
Jan.	7	15	8W	July	6	14	11E
	12	21	2		11	18	16
	17	23	45		16	21	58
	22	24	28		21	24	28
	27	23	58		26	26	20
Feb.	1	22	42		31	27	14
	6	20	55	Aug	5	27	5
	11	18	41W		10	25	31
					15	21	48
Mar.	23	13	6E		20	16	51E
	28	17	9				
Apr.	2	19	0	Sept.	9	15	39W
	7	18	27		14	17	49
	12	15	11E		19	16	53
					24	13	59
May	2	13	37W		29	10	5W
	7	19	19				
	12	23	1	Nov.	8	17	12E
	17	25	0		13	18	13
	22	25	22		18	20	4
	27	24	22		27	21	22
June	1	22	13		28	21	39
	16	18	55	Dec.	3	19	36
	11	14	36W		8	14	49E
				Dec.	23	16	1W
					28	20	59
					33	22	47W

The Equinoxes of the Planets: A partial reply to Query on page 222 POPULAR ASTRONOMY for April 1905.

Wolf's *Handbook of Mathematics* (in German) gives the following data regarding the Sun:

THE SUN.

Longitude of the ascending node of the Sun's equator on the Ecliptic	74°	37′
Inclination	6	58
Longitude of Sun's Pole	344	37

THE EARTH.

Longitude of ascending node of Earth's equator on the Ecliptic	180	0
Inclination	23	27
Longitude of the Celestial Pole	90	0
Latitude " " " "	66	33

Professor Young's *General Astronomy* gives in Appendix I the inclinations of the equators of some of the planets to their orbits but does not give the longitude of the nodes, without which the inclination cannot be reduced to the Ecliptic.

Planet.	Inclination of Equator to Orbit.
Venus	small
Earth	23° 27′ 08″
Mars	24 50
Jupiter	3 05
Saturn	26 49

The inclination of the other planets cannot be determined.

ROBERDEAU BUCHANAN.

Possible Effects of Radiation on the Motion of Comets.—In the *Monthly Notices* for January 1905 Mr. H. C. Plummer, of the University Observatory, Oxford, gives a very interesting discussion of the possible effects of radiation on the motion of comets. He refers to a memoir by Professor Poynting on "Radiation in the Solar System" (published in the *Philosophical Transactions* and reprinted in the *Memoirs* of the Royal Astronomical Society) and discusses the application of some of the formulas derived in the memoir to the movements of small meteoric bodies, such as are supposed to constitute the mass of a comet.

"To take an example, two spherical meteors of density 6.2 and radius 1 cm., possessing the temperature which they acquire at the same distance from the Sun as the Earth, neither attract nor repel one another, the gravitational stress being balanced by the radiation pressure. Facts such as this may well lead to a revision of the views at present held as to the stability of meteor swarms, the subject of a series of well known researches by Schiaparelli, Charlier, L. Picart and Callandreau. As Poynting suggests, such facts may have a bearing on the theory of Saturn's rings, provided the temperature of the planet is sufficiently high. Most significant of all, from the theoretical point of view, is the modification, though not of course the destruction in the physical sense, of the law of action and reaction. It seems just conceivable that the transformation of material momentum into ether-momentum may have important influences on a cosmic scale."

Mr. Plummer finds that the effect of radiation pressure is precisely analogous to that of a resisting medium in space and will tend to accelerate the mean motion of a particle in the same way, although the physical nature of the action is entirely different. There is a corresponding diminution in the distance from the Sun as may be shown by a numerical example taken from Poynting's paper: A

sphere of radius 1 cm., and density 5.5, starting with the velocity of the Earth and at its distance from the Sun will move inwards one ten-thousanth of its distance in about 20,000 years. If the same laws were applicable to a body actually as large as the Earth, the result would be to diminish the length of the year by one second in three billion years.

In applying the new theory to the actual case of Encke's comet, however, Mr. Plummer meets such difficulties that he says: "Consequently the difficulty of reconciling the suggested theory with the presumable state of the facts seems to be too great, and unless some serious error has been overlooked the attempt to explain the acceleration in the mean motion of Encke's comet by this particular deduction from the theory of radiation must apparently be regarded as an interesting but untenable speculation."

The Relative Brightness of Stars.—In the *Monthly Notices* of the Royal Astronomical Society for January 1905, Mr. J. E. Gore computes the magnitude of the Sun, if it were to be removed to the distances of a number of the stars whose parallaxes are comparatively well determined, and also the relative brightness of these stars as compared with the Sun.

Adopting as the Sun's stellar magnitude—26.5 (which is the same as assuming the Sun to be 100,000,000,000 times as bright as a first magnitude star,) he finds for the magnitude M of the Sun at the distance indicated by the parallax p of a star

$$M = 5 \log\left(\frac{1}{p}\right) + 0.07$$

Letting p be 0.37″, the parallax of Sirius, this formula gives 2.23 as the Sun's magnitude at the distance of Sirius. The photometric magnitude of Sirius is —1.58; the Sun would therefore be 3.81 magnitudes fainter than Sirius and according to the ordinary formula for relative brightness

$$\log \frac{b_1}{b_2} = 0.4\ (M_2 - M_1)$$

Sirius would be 33.4 times as bright as the Sun. In the same way Polaris is found to be 27.5, Aldebaran 35.0, Capella 128, Regulus 642, Arcturus 1486, etc., times as bright as the Sun.

The following table gives Mr. Gore's data and results for a few of the more familiar stars:

Star.	Photometric Mag.	Parallax ″	Sun's Mag. at Star's Dist.	Relative Brightness.	
β Cassiopeiæ	2.42	0.10	5.07	11.49	
η Cassiopeiæ	3.64	0.154	4.13	1.57	Mass = 1.622 Sun.
μ Cassiopeiæ	5.34	0.11	4.84	0.63	Proper Motion 3.″75.
Polaris	2.12	0.074	5.72	27.55	
Aldebaran	1.06	0.107	4.92	35.00	
Capella	0.21	0.081	5.48	128.23	Mass 12.7 Sun.
Sirius	—1.58	0.37	2.23	33.42	Mass 3.5465 Sun.
Procyon	0.48	0.325	2.51	6.49	Mass 3.627 Sun.
Regulus	1.34	0.022	8.36	642.7	
Groombridge 1830	6.47	0.15	4.19	0.122	Proper Motion 7.″05.
Arcturus	0.24	0.024	8.17	1486	
α Centauri	0.06	0.75	0.69	1.786	Mass 2.00 Sun.
Antares	1.22	0.021	8.46	787.04	
Vega	0.14	0.082	5.50	139.32	
Altair	0.89	0.231	3.25	87.91	
61 Cygni	4.96	0 39	2.11	0.07	Proper Motion 5.″16

Dr. Frank Schlesinger left the Yerkes Observatory April 3rd, to take the Directorship of the new Allegheny Observatory. His colleagues at the former place regretted his departure, but wished him every success in his new position. Those who are familiar with the ability he showed in his work at Columbia University and in the latitude determinations at the International Observatory at Ukiah: and especially those who know of the remarkable results he was getting in stellar parallaxes from photographs with the Yerkes 40-inch refractor, feel sure that the prestige attaching to the Allegheny Observatory from the labors of Langley and Keeler, will be well sustained under Dr. Schlesinger's leadership.

Astronomers of Today and their Work.—It is a good sign of the present time that so many useful books in science are being written by scholars fully competent for the tasks they seem willing to undertake. In this regard astronomy is having its full share of attention, both by the older and the younger men in the field.

The latest volume that has reached us is by Hector Macpherson, Junior, a member of the Astronomical Society of France, who writes on astronomers of today and their work. The publishers are Gall and Ingalls, 25 Paternoster Square, London E. C. England, or 20 Bernard Terrace, Edinburgh, Scotland. The work contains 252 pages, has 27 portraits, is put up in small demy, 8vo., form and costs 7s. 6d net.

The character of the book is of high grade; the young author has struck out in a new line of popular writing, by dealing with living astronomers and their work. It has long been the custom of those giving attention to biographical sketches to confine themselves to the work of scholars at the end of life when their work has been finished.

But in this instance we have not only the accounts of the life-work of more than a score of the most able and most noted astronomers now living, but also an assistance in preparing these sketches that is both unique and exceptionally satisfactory, in that the scholars themselves have materially aided in collecting the data that the author has needed to do his work completely and well.

This new volume has a fine cut of Sir William Huggins as a frontispiece, a fitting recognition of long scholarly service to astronomy which now stands well in the first rank of modern effective research in his chosen field of spectroscopy. The first sketch is that of the well-known Otto Wilhelm von Struve. We would have been glad to see a picture of his face; we miss that, in thinking of the grand old man as we read the brief but noble account of his life work. In the words of the author, it is "difficult to overestimate the services of Otto Struve to astronomy. Besides his work on Saturn's rings, on nebulae, and on the solar motion, he is one of the five greatest double-star observers who have ever lived. His reputation is an enduring one, and his name may well be placed among the greatest astronomers of the nineteenth century.

The account of Dr. Huggins is next, occupying ten pages. It sets forth well the esteem in which he is now held in all the world on account of what he has done. Many honors have been heaped upon him, and in his advanced age he still holds the place of a great scholar in astronomy and kindred branches.

Pierre Jules César Janssen's thoughtful face bent in meditation, and himself with pencil in hand to note down what he sees and thinks is the characteristic impress of this noted French scholar. His ambition and great success in solar physics and his masterful help in shaping the effective trend of it is set forth as the third account.

Next follow sketches of three of our own great American astronomers: Professors Asaph Hall, Charles Augustus Young, and Simon Newcomb, each an authority in his own sphere. The first and last have filled places in mathematical astronomy of very high rank. The scarcity of such talent now and prospectively in the future is plainly noticeable and it should be a hint to young men looking for most useful fields of labor in the future.

Professor Young as an author of a series of astronomical text-books stands easily in the first place in the world. This has all come about very naturally. An exact scholar from his youth, later at the head of a great observatory, and for more than thirty years a teacher of astronomy in college and university has given opportunity for large use of his ability in a needy field of work. Astronomy owes much to these three men.

Giovanni Virginio Schiaparelli the able Italian astronomer is next introduced to us, as the enthusiastic lover of "*the science of infinity and eternity.*" His young and bright looking face does not say that on March 14th last, he passed his seventieth birthday. Comparatively large space is given by the author to the work of this man who is really a genius in this field of the oldest science. A characteristic feature of his way of thinking is illustrated by his views of certain passages in the Old Testament as related to and explained by astronomy. The passage "Cans't thou lead forth Mazzaroth in their season" is explained by him through the aid he gets from the Latin version of the text in which the authorized version translates the word Mazzaroth, the planets." "Sun, Moon, Mazzaroth and all the host of heaven" has a definite meaning if this be the true sense of the word. Mazzaroth "in its season" might be a reference to the bright planet Venus, as Schiaparelli thinks, for the Hebrew people certainly would notice the brightest object in the heavens after the Sun and the Moon.

The contributions to astronomy by this versatile scholar have been many and varied, and for them he has been held at home and abroad in very high esteem.

Sir Joseph Norman Lockyer's sketch is next and we note the absence of his picture. He is probably best known through his theory of the evolution of the stars which the author presents fairly and quite fully for so brief an outline of much important astronomical work. Then follow Copeland of Scotland, Tacchini of Italy, S. W. Burnham of Yerkes Observatory noted as authority in double star astronomy; Dunér of Upsala Observatory, Sir Robert S. Ball, Professor Celoria of Milan Observatory, Agnes Mary Clarke, Camille Flammarion, Herman Carl Vogel, Sir David Gill, about each of whom there could be said much to their credit for the noble science that they all have served so well. Then follows a group of astronomers generally a little younger who are now in the front of active work and influence in directing astronomical research in various parts of the world. Of these the familiar names of John Ellard Gore, George H. Darwin, Edward Charles Pickering, William Frederick Denning, Hugo Seeliger, Jacobus Cornelius Kapteyn, Edward Walter Maunder, Aristarch Bélopolsky, Percival Lowell, Edward Emerson Barnard, William Henry Pickering, Julius Scheiner, William Wallace Campbell and Max Wolf completes the list which the author has chosen as leaders in the world's long and active skirmish line in the battle with impending problems in the advance of modern astronomy. This new book could not well be large enough to contain all the names of the young men that should be listed from this side of the sea, as well as those on the other side. We will name just one omission, that of the young and gifted George E. Hale now at the head of the Carnegie Solar Observatory which is building on Mt. Wilson, California.

Mr. Hector Macpherson, the author of this work, is probably the youngest scientific writer of the day; as all the sketches are the work of the leisure of the youthful astronomer. The clear exposition of the scientific details, the grasp of the various theories placed before the reader, and the intimate knowledge of the essential facts, show that in placing a work before the public giving so many interesting details about the astronomers of all countries, youth at least is no barrier or hindrance when the mind has its object clearly in view.

The editor of the "Edinburgh Evening News" may well be proud of the achievement of his son; and Science at least cannot fail to be grateful for the service rendered in bringing the astronomical work of all nations in review, in so popular a way.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the first of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription are sent directly after the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal, promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price to Popular Astronomy in the United States, Canada and Mexico is $2.50 per volume of 10 consecutive numbers. Price per volume of 10 numbers to foreign subscribers $3.00. Postage will be accepted only in payment of bills of fifty cents, or less. Volume begins with January number, but subscriptions may begin with any number.

All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.